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PACIFIC SCIENCE

A QUARTERLY DEVOTED TO THE BIOLOGICAL AND PHYSICAL SCIENCES OF THE PACIFIC REGION

IN THIS ISSUE: Parrott — *Australian* Poecilocryptus • Clark — *Indo-Pacific Echinoderms* • Stidd — *Estimates of Hawaiian Rainfall* • Yount — *Central Pacific Salpidae* • Hyman — *Polyclad Flatworms from the Hawaiian Islands* • de Laubenfels — *Sponges in an Aquarium* • St. John and Krauss — *Scientific Name of the Big Tree* • Petterssen — *The Swedish "Albatross" Cruise* • Voss — *Marshall Islands Cephalopods* • NOTES

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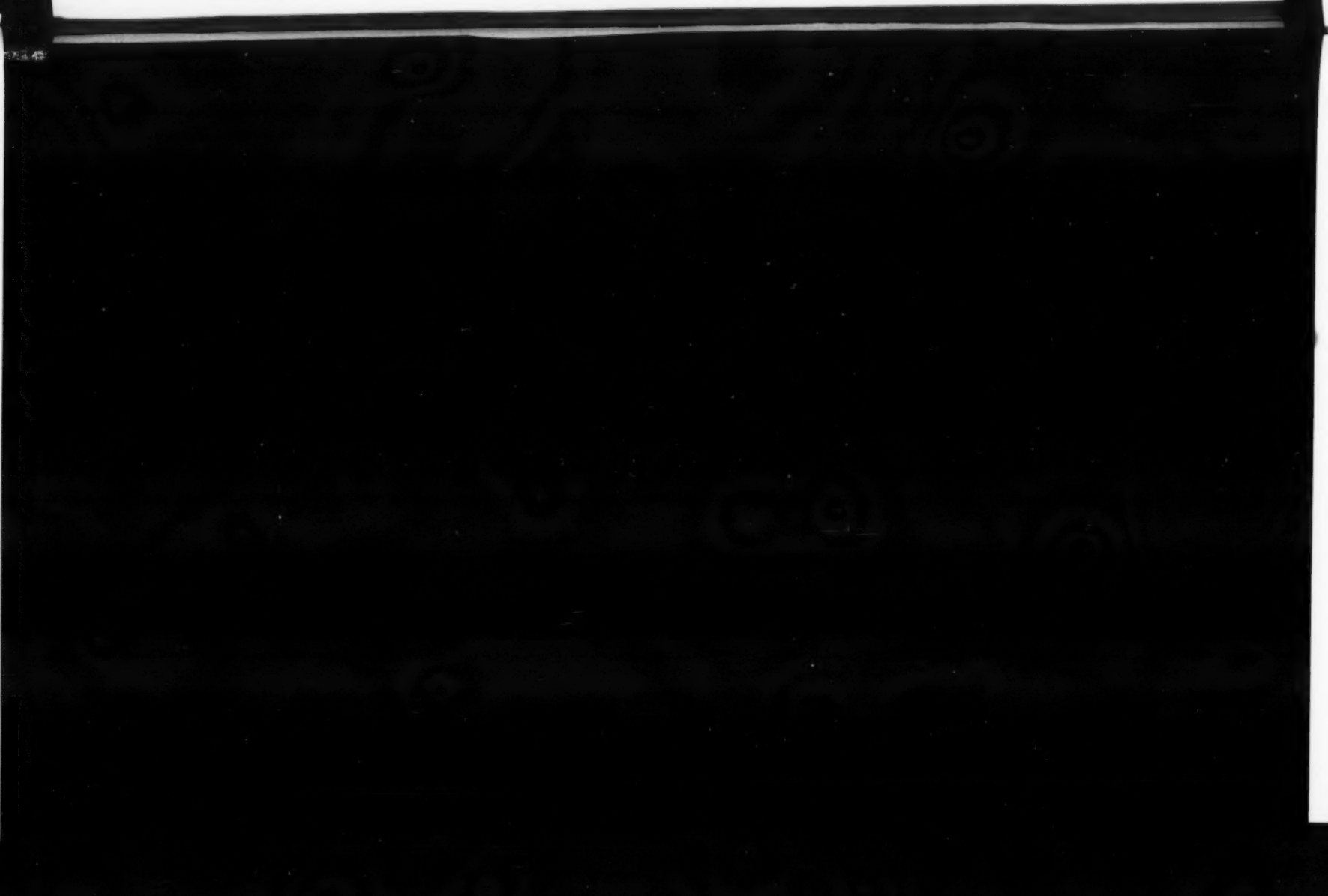
PREPARATION OF MANUSCRIPT

Although no manuscript will be rejected merely because it does not conform to the style of PACIFIC SCIENCE, it is suggested that authors follow the style recommended herein and exemplified in the journal.

(Continued on inside back cover)



PACIFIC SCIENCE

A QUARTERLY DEVOTED TO THE BIOLOGICAL AND PHYSICAL SCIENCES OF THE PACIFIC REGION

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Australian Species of *Poecilocryptus* Cameron (Ichneumonidae: Hymenoptera)[1]

ARTHUR W. PARROTT

CAMERON ESTABLISHED a new genus for a species of Australian Ichneumonidae, *Poecilocryptus nigromaculata*, in 1901. He gave a good description of the type and a clear generic diagnosis. The locality, however, is given vaguely as "Australia." Turner and Waterston (1920) described another species, from Tasmania, under the name *P. nigripectus*, and also recorded and figured Cameron's species from Tasmania.

Morley, in 1914, proposed a new name for Cameron's genus, because Kriechbaumer in the same year used *Poecilocryptus* for an entirely different insect from South America. Cushman (1936) has shown that Morley's action was not correct as Cameron's name was published in June, whereas Kriechbaumer's name was published later in the same year. Cushman further points out (1936: 465) that, in proposing *Poecilopimpla* for the supposedly preoccupied *Poecilocryptus* Cameron, Morley overlooked the fact that Cameron (1903: 140) had already used that name. Cushman has further pointed out that it is not necessary to rename *Poecilocryptus* Kriechbaumer, as the same genus was redescribed by Viereck under the name *Photocryptus*.

The systematic position of *Poecilocryptus* is not clear: it shows definite affinities to the pimplinids but also is somewhat allied to the cryptinids. Morley (1914: 35), who examined the type, states, "If not truly pimplid, at least very far removed from any known form of cryptid." Cameron (1901: 527) connected it with *Phygadeuonini*, though he remarks, "It has no relationship with any other genus." Turner and Waterston (1920: 24) state, "Cameron was probably correct in connecting the genus with the Phygadeuonini." Cushman (1936: 465) considered this genus to belong to the Cryptinae.

Genus POECILOCRYPTUS Cameron

Poecilocryptus Cameron, Ann. and Mag. Nat. Hist. 7(7): 527, 1901. (Nec Kriechbaumer, 1901.)

Poecilopimpla Morley, Rev. Ichneum. Brit. Mus., Pt. 3: 35, 1914. (Nec Cameron, 1903.)

Poecilocryptus Turner and Waterston, Zool. Soc. London, Proc. 1920: 24, figs. 8a, 11b.

Poecilocryptus Cushman, Wash. Acad. Sci., Jour. 26(11): 465, 1936.

Type species: *P. nigromaculatus* Cameron.

Morley (1914: 37) described *P. inflexa* from "Eastern Australia" which, judging from his description, is not correctly placed in this genus. Until the type is examined, the true position of *P. inflexa* will remain doubtful. Morley himself remarks that it probably merits generic rank, because of its vertically much narrower head, basally not discrete and apically truncate clypeus, prominent mandibles,

[1] Manuscript received February 25, 1953.

small and subpunctiform notauli, large and elongate metathoracic spiracles, the prominent petiolar spiracles, more deplanate abdomen, very large but slightly curved tarsal claws, straight discocubital nervure, centrally strongly incurved second recurrent and genicular nervellus, which emits a very strongly sinuate nervure to apex of the wing. I will not include *P. inflexa* Morley in *Poecilocryptus* Cameron.

Morley (1914: 36) describes some small specimens reared by Froggatt in 1892 from the swollen stems of *Acacia* leaves at Sydney, a male from *Agrizon* galls, Rose Bay, and a third specimen taken by French at Melbourne in 1900.

These specimens Morley considered a variety of *P. nigromaculata*, as he states: "I cannot regard as distinct a much smaller, clear stramineous form with the black markings very much sparser, the sides of the abdomen alone spotted and the legs immaculate: these modifications lend the insects a very different aspect, and the length is but 6–7 mm.; but the structure is in every way identical, and I will simply term it Var. *straminea*."

I have examined a series of a dozen specimens of this small form which Morley considered a variety of *P. nigromaculata* Cameron, and consider it to be without doubt a distinct species.

Although Morley stated that in structure it is in every way identical with *P. nigromaculata*, the specimens I have examined may be separated structurally from Cameron's species thus:

P. nigromaculata Cameron	*P. straminea* Morley
Postocellar space wider than the ocellocular space	Postocellar space equal to ocellocular space
Antennae longer than fore-wing, with less than 30 joints in flagellum	Antennae shorter than fore-wing, with more than 30 joints in flagellum
Ovipositor not as long as the abdomen	Ovipositor always longer than the abdomen, sometimes nearly 1½ times as long
Length 9–10 mm.	Length 5–7 mm.

On the above differences in structural characters, together with the constant differences in the distribution of the black markings on the abdomen, Morley's variety *straminea* is given specific rank.

KEY TO SPECIES *of poecilocryptus*

1. Radial side of areolet about twice as long as upper inner side of areolet and as long as or longer than lower outer side 2

   Radial side of areolet equal to upper inner side and shorter than lower outer side of areolet. A crest or tooth at apex of dentiparal area. Spiracles of petiole before middle . . . . . **P. nigripectus**

2. Antennae with over 30 joints in flagellum, shorter than length of fore-wing. Second, third, fourth, and fifth tergites of abdomen with lateral spots, more or less discrete. Ovipositor as long as or longer than abdomen . . . . . **P. straminea**

   Antennae with less than 30 joints in flagellum, and longer than length of fore-wing. Second, third, and fourth tergites of abdomen with wide basal transverse bands of black, sometimes strongly incised medially, but usually not separated into discrete dorsolateral spots. Fifth tergite has a broad transverse band not incised medially. Ovipositor not as long as abdomen . . . . . **P. nigromaculatus**

Poecilocryptus nigromaculatus Cameron

Poecilocryptus nigromaculatus Cameron, Ann. and Mag. Nat. Hist. 7(7): 528 ♀, 1901.

Poecilopimpla nigromaculata (Cameron) Morley, Rev. Ichneum. Brit. Mus., Pt. 3: 36, 1914.

Poecilocryptus nigromaculatus Cameron, Turner and Waterston, Zool. Soc. London, Proc. 1920: 26, 1920.

Poecilocryptus nigromaculatus Cameron, Cushman, Wash. Acad. Sci., Jour. 26(11): 465, 1936.

Cameron (1901: 528) vaguely records this species from "Australia." He later (1911: 335) states that Froggatt bred this species from reddish (*Eucalyptus*) berry-shaped galls in September near Inverall, New South Wales. Morley records it from Melbourne, Victoria, during August and September. Turner and Waterston (1920: 26) record it from Mt. Wellington, and Eaglehawk Neck, Tasmania, in January and March.

Material Studied

2 Warrendyte, Victoria, October, 1925. Coll. G. F. Hill. (D.S.I.R.O. Collections.)
2 Warrendyte, N. D. Coll. G. F. Hill. (D.S.I.R.O. Collections.)
4 Warrendyte, Victoria, collected July, 1925, "emerged August 1928." Coll. G. F. Hill.

Poecilocryptus straminea Morley

Poecilopimpla nigromaculata var. *straminea* Morley, Rev. Ichneum. Brit. Mus., Pt. 3: 37, 1914.

This species may be briefly characterized as follows:

As *P. nigromaculatus* Cameron but smaller (5–7 mm.), with the posterior ocelli about their diameter apart, the same distance separating them from the dorsal margin of eyes on either side; antennae subequal to length of fore-wing, and with under 30 joints in flagellum; ovipositor as long or longer than the abdomen; second, third, fourth, and fifth abdominal tergites having dorsolateral spots generally well separated medially; apex of posterior tibiae not infuscated. Morley, who first recognized this species as a variety of *P. nigromaculatus*, only noted the reduction of the black markings of the abdomen and the smaller size.

Morley (1914: 37) recorded this species from swollen stems of *Acacia* leaves at Sydney. In 1892 Froggatt bred the typical female and a male labeled "Agrizom. galls, Rose Bay."

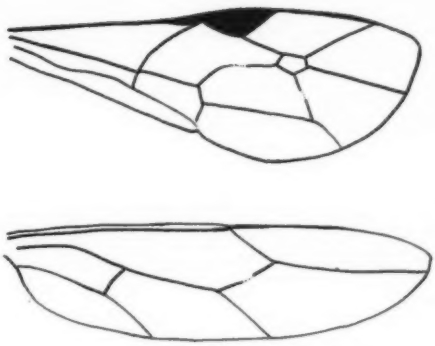

FIG. 1. Fore- and hind-wing of *Poecilocryptus straminea* Morley

A third specimen was captured by French at Melbourne during August, 1900.

Material Studied

1♂ (Holotype) Sydney. Coll. W. W. Froggatt. (D.S.I.R.O. Collection.)
1♂ (Paratype) Ourimbah, N.S.W., on *Acacia* galls, Dec., 1925. Coll. W. W. Froggatt. (D.S.I.R.O. Collection.)
1♂ (Paratype) No. 2055, leaf-stem gall. (D.S.I.R.O. Collection.)
1♀1♂ (Holotype: allotype) Box Hill, Victoria. "Bred from Galls with Gallflies." No. 16747 (identified by L. F. Graham as *P. nigromaculatus* Cameron). On the same card are a species of Chalcidoidea. (D.S.I.R.O. Collection.)
2♀1♂ "Blukistan"; gall on *E. obliques*, May–June, 1888, Smeatin. (S.A.M. Collection.) [The writing on these labels is very indistinct, but the locality, I think, is "Blukistan."]
2♀ Botanical Gardens (No. 2080), Dec., 1930. Coll. W. W. Froggatt. (D.S.I.R.O. Collection.)
1♀1♂ "Malli." Coll. W. W. Froggatt.

The material on which this paper is based was kindly lent by Dr. A. J. Nicholson, Chief,

Division of Entomology, D.S.I.R.O., Canberra, and Mr. Herbert M. Hale, Director of the South Australian Museum, Adelaide, to whom I extend my very sincere thanks for the loan of this interesting material.

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Records of Indo-Pacific Echinoderms

AUSTIN H. CLARK[1]

THE ECHINODERMS recorded herein were for the most part collected in connection with the studies of the Pacific Science Board, National Research Council. They represent incidental activities of 15 members of survey parties, all of whom were intensively engaged in other work. It has seemed advisable to supplement these records with those of other specimens from the Indo-Pacific region not previously recorded which were received from 15 donors, most of whom were members of the armed forces, chiefly during and after the war. The specimens from New Caledonia were presented to the National Museum by the late Lieutenant General Alexander McCarrell Patch, Jr., through the National Geographic Society.

All the specimens listed are in the United States National Museum. A large collection of echinoderms from the Marshall Islands, including 2,674 specimens resulting from the Navy's Operation Crossroads and the Bikini Scientific Resurvey, has previously been described (Clark, 1952). This paper should be consulted in connection with the present contribution.

All the sea urchins collected by Dr. F. S. MacNeil are dead tests.

Our knowledge of the details of the distribution of the littoral echinoderms of the Indo-Pacific is very limited, especially in regard to the central Pacific area. Extensive work has been done only in Australia, the Netherlands East Indies, the Malayan region, the Philippines, and the Hawaiian Islands, and even here the records, though very numerous, are very spotty.

About the large, high, forested islands where the available nutrients in the sea are enriched by a constant accession of vegetable waste from the land, the fauna, both littoral and abyssal, is exceedingly rich and varied, with many large species and unusually large individuals of other species. A curious side light on the importance of vegetable detritus is afforded by the flexible-shelled sea urchins of the genus *Araeosoma* which occur at depths of from 70 to 1,289 meters and are known to feed on the leaves of dicotyledonous plants. Even a fossil *Araeosoma* from California was surrounded by leaf impressions. In the Pacific area *Araeosoma* occurs among the Malayan Islands and the Philippines, off Tonga and Fiji, off southern Japan, and off the Galápagos Islands and Panama, but not in the central Pacific or on the American coast except at Panama. The species of *Araeosoma* are large, one of them up to 180 millimeters in diameter.

Although certain faunal subregions may be distinguished in the region of the larger and higher islands from Ceylon eastward, these are not very distinctive, the tropical Australian, including the Aru Islands and the south

[1] Curator, Division of Echinoderms, United States National Museum, Washington, D.C. Manuscript received August 12, 1953.

coast of New Guinea, being the most notable. Northward and eastward among the low islands, as conditions become less and less favorable for littoral echinoderms, the fauna becomes progressively poorer, and segregation into definite faunal regions appears to become more marked.

The majority of the Indo-Pacific species are small or at most of medium size and are present everywhere, though many become fewer in individuals among the atolls. In some cases the individuals here are noticeably smaller. The large species in many cases disappear or become segregated and confined to special areas in which they may become differentiated into recognizable subspecies or even distinct species.

The very large and heavy sea stars of the family Oreasteridae are especially characteristic of tropical coasts, but, except for the genus *Culcita*, the cushion stars, the most specialized of the family, ranging from east Africa eastward, they are absent from the central Pacific area. The largest genus, *Pentaceraster*, with 14 species, is found from the Red Sea and eastern Africa to Australia, New Guinea, New Britain, New Caledonia, and Samoa, and also on the coast of China, in the Philippines, among the Ryukyu Islands, in southern Japan, in the Hawaiian Islands, and on the west coast of Central America. The species found in the Hawaiian Islands and on the American west coast are very similar. The genus *Protoreaster*, with four species, ranges from eastern Africa to western Australia, New Guinea, the Bismarck Archipelago, New Caledonia, the Mariana Islands, the Palau Islands, Yap, the Ryukyu Islands, and southern Japan. If species of these two or related genera occurred among the atolls, they could scarcely be overlooked and certainly would be known to the natives.

Among the sea urchins the genus *Astropyga* is characteristic of tropical regions in from 5 to 88 meters. The species are large, up to 180 millimeters in diameter. They range from eastern Africa to Australia, New Britain, and the Hawaiian Islands. One species occurs from the Gulf of California to Panama, and another is known from off the Dry Tortugas, Florida. No species is known from the central Pacific, though one may occur there, as there is an old specimen in the Copenhagen Museum said to be from Nukahiva in the Marquesas; but Dr. Mortensen regards the locality as doubtful. Too much faith cannot be placed on the absence of records of this genus, as the species seem to be easily overlooked. The Caribbean species was not described until 1934 and is still known only from the four original specimens.

Among the brittle stars, the very large and conspicuous basket stars of the family Gorgonocephalidae, otherwise cosmopolitan, have not been reported from the small islands, nor have any of the species of Trichasteridae, with many-branched arms. However, the species of these two families occur in water of from a few fathoms downward, not along the shores, so, although they are frequently brought up on fishermen's lines, the absence of records is not necessarily significant.

Among the more conspicuous and characteristic of Indo-Pacific sea urchins are the limpet, pavement, or helmet urchins of the genus *Colobocentrotus*. These are of fairly large size and live in the surf zone, usually in large colonies, so that they are not easily overlooked. One species, *C. atratus*, occurs at Zanzibar, Natal, Madagascar, Mauritius, the Seychelles, Christmas Island, Java, Timor, and Amboina, and also in the Hawaiian Islands, though not between the Moluccas and Hawaii. A related species, *C. pedifer*, is confined to the Tuamotus. A third species, *C. mertensi*, is found in the Bonin and Mariana Islands. A related genus with normal instead of modified spines, *Zenocentrotus*, occurs in Tonga and Samoa. The latter, first described in 1931, may have a more extended distribution as it is easily confused with sea urchins of other families.

Among the largest, most conspicuous, and most characteristic of the Indo-Pacific sea

urchins are the two species of slate-pencil or cigar urchins of the genus *Heterocentrotus*. One of these, *H. mammillatus*, occurs from the Red Sea and Tanganyika, Madagascar, Mauritius, and Rodriguez to the Cocos-Keeling Islands, northwestern Australia, New Guinea, Torres Strait, the Philippines, New Caledonia, and Fiji, and also in the Mariana, Bonin, Ryukyu, and Hawaiian Islands. It appears to be absent from the central Polynesian region except for Johnston Island and the Tuamotus, where it was recently found by Dr. Morrison.

The other more specialized species, *H. trigonarius*, occurs at Zanzibar, Natal, Madagascar, Mauritius, Rodriguez, Java, the Philippines, Tonga, Samoa, and throughout Polynesia.

Both species occur at Madagascar, Mauritius, Rodriguez, the Philippines, the Tuamotus, and Johnston Island.

As both species have apparently the same habits, living normally in holes and crevices in the reefs and sometimes together in the same group, the reason for the difference in distribution in the extreme western and in the eastern part of their ranges is obscure. It may, of course, be due in part to insufficient knowledge of their distribution among the atolls; *H. mammillatus* may be more generally distributed here than the records available at present indicate.

It appears somewhat paradoxical that, although large species and large individuals for the most part do not extend into the groups of small Polynesian islands, a few species reach their maximum size in this area, on the northeastern periphery of their range. The largest specimen of *Heterocentrotus trigonarius* I have seen is from Johnston Island and measures 123 by 100 millimeters with a height of 68 millimeters and with the longest spines 150 millimeters. In another specimen, possibly larger, the longest spines are 165 millimeters long. Some from Bikini are almost as large (Clark, 1949: 71). The largest known specimens of *Brissus latecarinatus* are those from the Marshall Islands recorded in the following pages.

In the Atlantic, *Echinometra lucunter* reaches its maximum size on the northern and southern limits of its range in Bermuda and Brazil (Clark, 1933: 83), and *Brissus brissus* in the Mediterranean reaches nearly twice the size that it does in the Caribbean (*ibid.*, p. 91). The largest known specimen of *Linckia guildingii*, with a radius of 215 millimeters, is from Bermuda.

From the zoogeographical and historical points of view, the most interesting and significant echinoderms are not to be found in the warm and brilliantly illuminated tropical littoral, but in the dimly illuminated and cooler zones from 5 or 6 fathoms downward to the depth, which differs in different areas, where a localized fauna, if present, begins to merge into the increasingly widespread abyssal fauna. That such an intermediate fauna may be of much significance is indicated by the genus *Psychocidaris*, the only representative of the family Psychocidaridae, related to the Cretaceous *Tylocidaris*, known only from the Bonin Islands in about 100 fathoms.

COLLECTION DATA

Onotoa Atoll, Gilbert Islands

The localities in the Onotoa Atoll, Gilbert Islands, are listed by numbers. The data for each numbered locality are as follows.

G.O.C.–24. Toward the southern end of a lee reef stretch known as Rakai Ati, in an area of small coral patches fairly thickly interspersed on lime sand and coral debris; the bottom is at depths of 3–4 feet at low tide. Preston E. Cloud, Jr., and D. W. Strasburg, July 26, 1951.

G.O.C.–25. About 4.25 miles S.86°W. from Aiki Maneaba on the lagoon side of the broad reef passage north of a narrower passage called Rawa Bao, from small patch reefs rising to within 4–6 feet of the surface from a lime-sand and coral-gravel bottom at 12 feet. P.

E. Cloud, Jr., A. H. Banner, and D. W. Strasburg, July 27, 1951.

G.O.C.–26. From an isolated patch reef in the main reef passage about 1.5 miles directly offshore from Government Station jetty (on south portion of northern main island); depth about 20 feet. A. H. Banner and D. W. Strasburg, July 28, 1951.

G.O.C.–27. About 9,200 feet S.72°W. from offshore end of Government Station jetty (on south portion of northern main island) just south of main passage out of lagoon (Rawa ni Karoro) where coral shoals known as Aon te ra Bata begin to deepen; collection made from an area where patch reefs rise above the lime-sand bottom, at 16 feet depth; most specimens from a low coral patch about 14 feet below the surface. P. E. Cloud, Jr., July 29, 1951.

G.O.C.–28. Slightly less than 4 miles N.-85°W. from Aiaki Maneaba in outer lagoon; patch reefs rising above the lime-sand surface at 14 feet to within 6 feet of the surface. P. E. Cloud, Jr., D. W. Strasburg, A. H. Banner, E. Moul, and J. Randall, July 30, 1951.

G.O.C.–29. About 1 mile S.32°W. from Tekawa church at lagoon margin of south end of reef stretch known as Aon te Baba; collection from patch reefs rising about 9 feet (reduced to mean low tide) lime-sand bottom to within 1 foot of the surface. P. E. Cloud, Jr., D. W. Strasburg, and A. H. Banner, July 31, 1951.

G.O.C.–30. *Heliopora* flat at south end of the northern main island of Onotoa at 1+ feet at low tide. P. E. Cloud, Jr., and D. W. Strasburg, August 1, 1951.

G.O.C.–32. Back ridge trough, about 600 feet offshore from PSB camp (Onotoa) at the outer margin of the windward reef, just inshore from the algal ridge and surge channels; this part of the reef never dries even at low tide and generally has at least a foot or two of water above it. P. E. Cloud, Jr., August 1, 1951.

G.O.C.–35. About 8,600 feet N.18°W. from Tabuarorae Maneaba in 17 feet of water at mean low tide. P. E. Cloud, Jr., August 10, 1951.

G.O.C.–36. Southeastern end of reef area known as Rakai Ati, south side of big windward point of reef near center of the atoll; collection made from a strip about 0.5 mile long running clear across the reef. P. E. Cloud, Jr., August 20, 1951.

G.O.C.–39. Northwestern Onotoa, about 1,300 feet northeast from Namokoro, in an area of gravelly sand bottom with maximum depths of about 12–14 inches at low tide and with occasional heads of digitate *Porites lobata*. P. E. Cloud, Jr., August 21, 1951.

G.O.C.–41. Green algal flats crusting dead coral-algal rock at northwest corner of atoll; collections were made over an area extending about 300 feet north and 1,000 feet west from a point about 3,000 feet north of the monument on Aonteuma; the area is exposed at low tide. P. E. Cloud, Jr., August 21, 1951.

G.O.C.–51. About 3.25 miles N.31°W. from Tabuarorae Maneaba near the center of Te Rawa ni Bao, a pass in the south part of the leeward reef; collected from thickly set coral masses rising from 15 feet (sounded at low tide) of water to within about 8–10 feet of the surface locally. P. E. Cloud, Jr., August 23, 1951.

G.O.C.–53. About 9,300 feet N.30°W. from Tabuarorae Maneaba in southern part of Te Rawa Tekatobibi, a pass through the south end of the leeward reef; collected from patch reefs rising to an occasional maximum of within 4 feet of the surface from a bottom sounded at 18 feet. P. E. Cloud, Jr., August 23, 1951.

G.O.C.–54. About 3,500 feet N.20°E. from Tabuarorae Maneaba, near the south end of the atoll, in about 2 feet of water over dead coral-algal bottom patchily veneered with calcareous gravel and scattered small patches of living coral. P. E. Cloud, Jr., August 23, 1951.

G.O.C.–55. About 13,400 feet S.75°W. from Aiki Maneaba in the deep central part of the lagoon; the bottom is of low scattered

dead and living coral patches on intervening lime sand and lime mud about 30–40 per cent sediments and 60–70 per cent coral. P. E. Cloud, Jr., August 25, 1951.

Banner, A–1, A–2. Windward reef flat, July, 1951.

Banner, A–11. Same locality, July 24, 1951.

Banner, B–1. Extensive shallow sand flats near shore.

Banner, B–4. Sand and decadent coral reef.

Banner, B–4–6. Sand and decadent coral reef, turtle grass, and mud flat, and "incipient beach rock," July, 1951.

Banner, B–8. Decadent coral reef.

Tuamotu Archipelago

The specimens from the Tuamotus were supplied with tin tag numbers in the field, and these numbers are listed under the species. The data for these numbers are as follows:

1841. Raroia Atoll, Ngarumaoa Island, zone just behind the outer reef edge. Joseph P. E. Morrison, July 5, 1952.

1842. Ngarumaoa Island, middle section or zone of outer reef. J. P. E. Morrison, July 5, 1952.

1855. Ngarumaoa Island, from edge of outer reef opposite village. J. P. E. Morrison, July 6, 1952.

1860. Ngarumaoa Island, middle zone of outer reef opposite village, on and under coral rock. J. P. E. Morrison, July 6, 1952.

1861. Ngarumaoa Island, from under rocks on middle to inner section or zone of outer reef opposite village. J. P. E. Morrison, July 6, 1952.

1879. Ngarumaoa Island, outer reef edge. J. P. E. Morrison, July 8, 1952.

1884. Ngarumaoa Island. J. P. E. Morrison, July 8, 1952.

1886. Ngarumaoa Island. J. P. E. Morrison, July 8, 1952.

1889. Ngarumaoa Island, from middle zone of outer reef flat. J. P. E. Morrison, July 9, 1952.

1906. Ngarumaoa Island, inshore pool area of outer reef at north end. J. P. E. Morrison, July 9, 1952.

1917. Ngarumaoa Island, from under side of, and boring into, coralline rocks just below low-tide line on inner reef at north end of island. J. P. E. Morrison, July 11, 1952.

1920. Ngarumaoa Island, outer reef flats. N. D. Newell, July 11, 1952.

1921. Ngarumaoa Island, outer reef flats. N. D. Newell, July 11, 1952.

1922. Fakatomo Island, outer reef. Robert Harry, July 11, 1952.

1952. Nataira Island, under rocks on outer reef flats. J. P. E. Morrison, July 16, 1952.

1959. Homohomo Island, round depressions in outer reef pavement edge. J. P. E. Morrison, July 21, 1952.

1963. Homohomo Island. J. P. E. Morrison, July 21, 1952.

1994. North of Kahongi Island. J. P. E. Morrison, July 25, 1952.

2002. Tahuna riri Island, outer reef pavement flats. J. P. E. Morrison, July 27, 1952.

2023. Ngarumaoa Island, off inner reef, south end of island, 15 feet depth. N. D. Newell, August 1, 1952.

2040. Oneroa Island, outer reef pavement area. J. P. E. Morrison, August 4, 1952.

2043. Oneroa Island, from outer reef lithothamnion ridge in one local area. J. P. E. Morrison, August 4, 1952.

2050. Oneroa Island, from the lithothamnion ridge of outer reef outside the island, 0.5 mile south of camp. J. P. E. Morrison, August 5, 1952.

2059. Oneroa Island, from edge of inner reef, lagoon shore. M. Doty, August 5, 1952.

2060. Raroia Atoll, from patch reef 2 kilometers inside southeast corner of lagoon. R. Harry, August 4, 1952.

2103. Oneroa Island, coral gravel talus to lagoon mouth of channel and north end of island, 10 feet depth. J. P. E. Morrison, August 9, 1952.

2116. Ngarumaoa Island, Ohave teu patch reef. J. Newhouse, August 12, 1952.

2118. Raroia Atoll, in lagoon 100 yards east of Ohave Karena patch reef, 60 feet depth. J. Newhouse, August 12, 1952.

2120. In the lagoon 200 yards south of Okumekume patch reef. J. Newhouse, August 12, 1952.

2121. In the lagoon 200 yards northeast of the eastern tip of Miramiruau reef, Ngarumaoa Island; 55 feet depth. J. Newhouse, August 13, 1952.

2122. Ngarumaoa Island, in lagoon 100 yards east of north edge of reef flat (Miramiruau), south end of island; in 40 feet of water. J. Newhouse, August 13, 1952.

2124. Ngarumaoa Island, in lagoon 400 yards southwest of Tomanganga patch reef. J. Newhouse, August 13, 1952.

2172. Brought in by Kahea from patch reef off Tapatahiti Island (lagoon). J. P. E. Morrison, August 23, 1952.

2184. Rocky (coral gravel) beach of sand island (no name), second channel east of Kakapuka Island. J. P. E. Morrison, August 26, 1952.

2185. Second channel east of Kakapuka Island, under rocks just below low-tide line on beach of sand island (no name). J. P. E. Morrison, August 26, 1952.

2236. Collected from coral-studded bottom in the Ava pass. Huri Estill, September 1, 1952.

2238. Ngarumaoa Island, from inner reef in sandy patch near reef edge only, north end of island. J. P. E. Morrison, September 2, 1952.

2245. Ngarumaoa Island, from just below and 1 foot below low-tide line on gravel and rocks of sandy gravel bottom, inner reef flats near shore. J. P. E. Morrison, September 2, 1952.

2250. Ngarumaoa Island, northern end. J. P. E. Morrison, September 3, 1952.

2252. Ngarumaoa Island, from coralline algae from outer reef. M. Doty, September 3, 1952.

2253. Ngarumaoa Island, south end, from pool and pavement zone. M. Doty, September 3, 1952.

2254. Ngarumaoa Island, edge of pond section of lagoon reef flat (Miramiruau), south of village. M. Doty, September 3, 1952.

LIST OF SPECIES COLLECTED

Class CRINOIDEA

Family *COMASTERIDAE*

Genus COMASTER L. Agassiz

Comaster gracilis (Hartlaub)

Actinometra gracilis Hartlaub, Nachr. Ges. Göttingen, May, 1890, pp. 170, 187 (Pulo Edam, near Batavia [Djakarta], Java).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–25 (1 specimen); G.O.C.–53 (1 specimen).

Genus COMANTHERIA A. H. Clark

Comantheria polycnemis A. H. Clark

Comantheria polycnemis A. H. Clark, U. S. Natl. Mus., Proc. 36: 396, 1909 ("Albatross" stations 5139, 5147, 5248, 5249 [type locality], 5350, 5251, 5252, 5253, 5354).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–25 (2 specimens); G.O.C.–53 (2 small specimens).

NOTE: A note with the specimens from G.O.C.–53 reads: "These and other ones lacking tendril grips [cirri] on base maroon with a scattering of golden threads on terminal (small) branches [pinnules] of food-gathering arms."

Genus COMANTHUS A. H. Clark

Comanthus bennettii (J. Müller)

Alecto bennettii J. Müller, Preuss. Akad. der Wiss., Monatsber. 1841: 187 (locality unknown).

LOCALITIES: Marshall Islands, Arno Atoll (3 small specimens); M.A.C.–1 (1 small specimen).

New Caledonia (1 large specimen).

Comanthus samoana A. H. Clark

Comanthus (*Comanthus*) *samoana* A. H. Clark, U. S. Natl. Mus., Proc. 37: 30, 1909 (Samoa).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–25 (8 specimens); G.O.C.–51 (1 specimen); G.O.C.–53 (6 specimens).

Comanthus parvicirra (J. Müller)

Alecto parvicirra J. Müller, Preuss. Akad. der Wiss., Monatsber. 1841, p. 185 (locality unknown).

LOCALITY: Gilbert Islands, Onotoa Atoll, G.O.C.–25 (4 specimens):

Genus COMATELLA A. H. Clark

Comatella maculata (P. H. Carpenter)

Actinometra maculata P. H. Carpenter, "Challenger" Rpts., Zoology 26(60): 307, 1888 ("Challenger" station 186).

LOCALITY: Mariana Islands, Rota, D. G. Frey, November 12, 1945 (1 specimen).

Family *HIMEROMETRIDAE*

Genus HIMEROMETRA A. H. Clark

Himerometra robustipinna (P. H. Carpenter)

Actinometra robustipinna P. H. Carpenter, Leyden Mus., Notes 3: 201, 1881 (Moluccas).

LOCALITY: Solomon Islands, New Georgia, Wilfred G. Iltis (1 specimen).

Family *MARIAMETRIDAE*

Genus STEPHANOMETRA A. H. Clark

Stephanometra spicata (P. H. Carpenter)

Antedon spicata P. H. Carpenter, Leyden Mus., Notes 3: 190, 1881 (Banda Sea).

LOCALITY: Guam, tide pools, D. G. Frey, November 25, 1945 (1 specimen).

Stephanometra indica protectus (Lütken)

Antedon protectus Lütken, Mus. Godeffroy Cat. 5: 190, 1874 (Tonga Islands; nomen nudum); in P. H. Carpenter, Linn. Soc. London, Trans. (Zool.), ser. 2, 2: 19, 1879 (character of the oral pinnules).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–25 (1 small specimen); G.O.C.–51 (1 specimen).

Okinawa, reef off Odomari, A. R. Loeblich, Jr., June 12, 1945 (3 specimens).

Genus LAMPROMETRA A. H. Clark

Lamprometra palmata palmata (J. Müller)

Alecto palmata J. Müller, Preuss. Akad. der Wiss., Monatsber. 1841: 185 (India).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–25 (1 specimen). Philippines, Green Island Bay, Palawan, Lt. William A. Bartos, 1944 (1 specimen).

Class ECHINOIDEA

Family *CIDARIDAE*

Genus EUCIDARIS Pomel

Eucidaris metularia (Lamarck)

Cidarites metularia Lamarck, Histoire naturelle des animaux sans vertèbres, vol. 3, p. 56, 1816 (Ocean of the Great Indies, Mauritius, and Santo Domingo).

LOCALITIES: Tuamotus, Morrison, 1879 (1 specimen); 1941 (1 specimen); 1952 (1 specimen).

Guam, Oca Point, D. G. Frey, November, 1945 (1 specimen).

Genus PHYLLACANTHUS Brandt

Phyllacanthus imperialis (Lamarck)

Cidarites imperialis Lamarck, Histoire naturelle des animaux sans vertèbres, vol. 3, p. 54, 1816 (Red Sea).

LOCALITY: New Caledonia (fragments of several specimens).

Family *DIADEMATIDAE*

Genus DIADEMA Gray

Diadema paucispinum A. Agassiz

Diadema paucispinum A. Agassiz, Mus. Compar. Zool., Bul. 1: 19, 1863 (Sandwich [Hawaiian] Islands).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–24 (1 specimen); G.O.C.–30 (1 specimen); G.O.C.–36 (1 specimen).

Diadema setosum (Leske)

Echinometra setosa Leske, Additamenta ad Jacobi Theodori Klein, 1778, p. 36.

LOCALITY: Saudi Arabia, ¼ mile north of West Pier, Ras Tanura, Donald S. Erdman, June 23, 1948.

NOTES: In his account of the echinoderms of the Iranian Gulf (Danish Scientific Investigations in Iran, part 2: 59, 1940) Dr. Th. Mortensen says: "Above all it is unbelievable that *Diadema* should not occur there, seeing that it occurs as far north as the Gulf of Suez in the Red Sea." In his notes on the echinoderms of Tarut Bay and vicinity, Saudi Arabia, Richard LeBaron Bowen wrote (A. H. Clark, 1949, Amer. Mus. Novitates No. 1390: 11, 13, 14) that on May 25, 1945, he found *Diadema* in Tarut Bay, and in one locality it was predominant and common. Later when he visited the locality to collect specimens, it had totally disappeared. In 1948 Mr. Erdman collected a specimen in the same general region and brought it to Washington. This specimen was mentioned as *Diadema setosum*, but without data of occurrence, in 1950 (Report on the Progress and Condition of the United States National Museum for the year ending June 30, 1949, p. 29).

Genus ECHINOTHRIX Peters

Echinothrix diadema (Linné)

Echinus diadema Linné, Systema naturae, ed. 10, vol. 1, p. 664, No. 7, 1758 (Indian Sea).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–24 (2 small specimens, one with a parasitic gastropod).

Marshall Islands, Ailuk Atoll, leeward reef just west of Ailuk Island, seaward side, F. S. MacNeil, 1951–52 (2 specimens).

Tuamotus, Morrison, 1842 (4 specimens); 2238 (1 specimen).

Guam, Oca Point, David H. Johnson, May, 1945 (1 specimen); D. G. Frey, November, 1945 (3 specimens).

Saipan, Unai Taloforo, P. E. Cloud, Jr., June 12, 1949 (1 specimen).

Echinothrix calamaris (Pallas)

Echinus calamaris Pallas, Spicilegia zoologica . . . vol. 1, fasc. 10, p. 31, pl. 2, figs. 4–8, 1774 (East Indies).

LOCALITY: Solomon Islands, Bougainville Island, U. S. Navy, 1944 (1 specimen).

Family *TEMNOPLEURIDAE*

Genus MESPILIA Desor

Mespilia globulus (Linné)

Echinus globulus Linné, Systema naturae, ed. 10, vol. 1, p. 664, No. 2, 1758 (Indian Ocean).

LOCALITY: New Caledonia (6 bare tests).

Family *TOXOPNEUSTIDAE*

Genus TRIPNEUSTES L. Agassiz

Tripneustes gratilla (Linné)

Echinus gratilla Linné, Systema naturae, ed. 10, vol. 1, p. 664, No. 4, 1758 (Indian Ocean).

LOCALITIES: Gilbert Islands, Onotoa Atoll, reef near Abenecne, at a depth of 2 feet, Banner, October 7, 1951 (collected by Strasburg) (1 specimen).

Tuamotus, Morrison, 1889 (1 specimen); 1921 (1 specimen); 2175 (1 specimen).

Palmyra Island, Dr. W. H. Jones, U. S.

Navy, U.S.S. "Portsmouth" (1 specimen).

Guam, Oca Point, David H. Johnson, May, 1945 (1 specimen).

Solomon Islands, Bougainville, U. S. Navy, 1944 (1 specimen); New Georgia, Wilfred G. Iltis (1 specimen).

Seleo Island, about 5 miles off the northern New Guinea coast at Aitape, about midway between Hollandia and Wewak, Capt. Marvin Clinton Meyer (3 specimens).

New Caledonia (1+ specimens).

Family *PARASALENIIDAE*

Genus PARASALENIA A. Agassiz

Parasalenia pöhlii Pfeffer

Parasalenia pöhlii Pfeffer, Ver. Naturw. Unterhalt. Hamburg, Verhandl. 6: 110, 1887 (Tahiti).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–28 (1 specimen).

Tuamotus, Morrison, 2250 (1 specimen).

New Caledonia (2 bare tests).

Family *ECHINOMETRIDAE*

Genus ECHINOMETRA Gray

Echinomatra mathaei (de Blainville)

Echinus mathaei de Blainville, Dict. de sci. nat., vol. 37, Oursin, p. 94, 1825 (Mauritius).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–24 (3 specimens); G.O.C.–27 (1 specimen); G.O.C.–29 (1 specimen); G.O.C.–36 (2 specimens); G.O.C.–41 (2 specimens); Banner, A–11 (1 specimen); lagoon, in coral, Banner, July, 1951 (1 specimen).

Marshall Islands, Ailuk, F. S. MacNeil (1 specimen); Eniwetok, Lt. William C. Harrington, July 9, 1944 (1 specimen); Kwajalein Atoll, Loi and South Loi Islands, F. S. MacNeil (4 specimens); Lae Atoll, Lae Island, F. S. MacNeil (1 specimen); Taka Island, beach, F. S. MacNeil (3 specimens); Ujae Atoll, Ally Island, F. S. MacNeil (1 specimen); Ujelang Atoll, sand bar east of Moron Island, F. S. MacNeil (2 specimens); Uterik Atoll, beach at west end of Uterik Island, lagoon side, F. S. MacNeil (1 specimen).

Tuamotus, Morrison, 1860 (3 specimens); 1879 (4 specimens); 1994 (1 specimen); 2116 (fragments); 2118 (dead test); 2184 (1 specimen); 2253 (1 small specimen).

Guam, Oca Point, David H. Johnson, May, 1945 (3 specimens); D. G. Frey, November, 1945 (3 specimens).

Saipan, P. E. Cloud, Jr., April 6, 1949 (1 specimen); lagoon west of Saipan, P. E. Cloud, Jr., April 12, 27, May 13, June 20, 1949 (19 specimens).

Okinawa, reef off Ogimi, A. R. Loeblich, Jr., June 12, 1945 (32 specimens).

Solomon Islands, Bougainville, Lt. William A. Bartos, 1944 (1 specimen); U. S. Navy, 1944 (2 specimens).

Seleo Island, about 5 miles off Aitape, northern New Guinea, about midway between Hollandia and Wewak, Capt. Marvin Clinton Meyer (5 specimens).

Netherlands New Guinea, about 5 miles north of Sansapor, Lt. George H. Penn, August 15 to October 3, 1944 (11 specimens).

New Caledonia (8 tests).

Echinometra mathaei var. **oblonga** (de Blainville)

Echinometra oblongus de Blainville, Dict. de sci. nat., vol. 37, Oursin, p. 95, 1825 (no locality).

LOCALITIES: Tuamotus, Morrison, 1841 (17 specimens); 2002 (1 specimen); 2185 (9 specimens).

Genus ECHINOSTREPHUS A. Agassiz

Echinostrephus aciculatus A. Agassiz

Echinostrephus aciculatus A. Agassiz, Mus. Compar. Zool., Bul. 1: 20, 1863 (Kingsmill [Gilbert] and Hawaiian Islands).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–51 (5 specimens).

Marshall Islands, Kwajalein Atoll, Loi and

South Loi Islands, F. S. MacNeil (1 specimen); Ujae Atoll, Wotya Island, F. S. MacNeil (1 small specimen); Ujelang Atoll, sand bar east of Moron Island, F. S. MacNeil (1 specimen).

Genus COLOBOCENTROTUS Brandt

Colobocentrotus atratus (Linné)

Echinus atratus Linné, Systema naturae, ed. 10, vol. 1, p. 655, 1758.

LOCALITY: Spouting Horn, south shore of Kauai, Hawaiian Islands, P. E. Cloud, Jr., September 13, 1951 (25 specimens).

Colobocentrotus pedifer (de Blainville)

Echinus pedifer de Blainville, Dict. de sci. nat., vol. 37, Oursin, p. 97, 1825 (southern seas).

LOCALITIES: Tuamotus, Morrison, 1922 (1 specimen); 1959 (1 specimen); 2043 (7 specimens); 2050 (5 specimens).

NOTE: This species is known only from the Tuamotus.

Colobocentrotus mertensi Brandt

Colobocentrotus mertensi Brandt, Prodrom. descr. anim. ab H. Mertensio observ., p. 66, 1835.

LOCALITIES: Guam, Oca Point, David H. Johnson, May, 1945 (8 specimens).

Saipan, near Taloforo, Alice Davis and Betsy Weld, transmitted through P. E. Cloud, Jr., June 12, 1949 (49 specimens).

NOTES: This species, long known from the Bonin Islands, was first recorded from the Marianas by Shozo Nishiyama who listed it from Pagan Island (Japan Oceanogr. Soc., Jour. 1[1,2], May, 1942 [in Japanese]). In 1949 I mentioned its occurrence at Guam (A. H. Clark, 1949; 71).

Genus HETEROCENTROTUS Brandt

Heterocentrotus trigonarius (Lamarck)

Echinus trigonarius Lamarck, Histoire naturelle des animaux sans vertèbres, vol. 3, p. 51, 1816 (?Mediterranean).

LOCALITIES: Marshall Islands, Ailuk, F. S. MacNeil (1 specimen); Kwajalein Atoll, Loi and South Loi Islands, F. S. MacNeil (1 specimen); Lea Atoll, on windward reef flat, Lea Island, F. S. MacNeil, 1951–52 (1 specimen); Likiep Atoll, Lado Island, outer reef behind lithothamnion ridge, F. S. MacNeil (2 specimens); Uterik Atoll, Uterik Island, F. S. MacNeil (2 specimens); Wotho, F. S. MacNeil (2 specimens).

Tuamotus, Morrison, 1855 (4 specimens); 1889 (1 specimen); 1959 (1 small specimen).

Canton Island, Charles A. Ely, November 18, 1941 (1 specimen).

Guam, Oca Point, David H. Johnson, May, 1945 (2 specimens).

Heterocentrotus mammillatus (Linné)

Echinus mamillatus Linné, Systema naturae, ed. 10, vol. 1, p. 664, No. 9, 1758 (no locality).

LOCALITIES: Tuamotus, Morrison, 1959 (3 small specimens).

Saipan, near Taloforo, P. E. Cloud, Jr., June 12, 1949 (2 specimens).

New Caledonia (8 bare tests).

Family *CLYPEASTRIDAE*

Genus CLYPEASTER Lamarck

Clypeaster latissimus (Lamarck)

Scutella latissima Lamarck, Histoire naturelle des animaux sans vertèbres, vol. 3, p. 12, 1816 (?Southern Ocean).

LOCALITY: New Caledonia (1 specimen, 110 by 104 mm.).

Clypeaster reticulatus (Linné)

Echinus reticulatus Linné, Systema naturae, ed. 10, vol. 1, p. 606, No. 15, 1758 (American Ocean).

LOCALITIES: Marshall Islands, Taka Atoll, F. S. MacNeil (1 specimen, length 75 mm.,

width at anterior pair of petals 54 mm., thickness of margin 13 mm.); Ujae Atoll, Ally Island, F. S. MacNeil (3 specimens).

Family *LAGANIDAE*

Genus LAGANUM Linck

Laganum depressum L. Agassiz

Laganum depressum L. Agassiz, Monographie des scutelles, p. 110, pl. 23, figs. 1–7, 1841 (Moluccas).

LOCALITIES: Marshall Islands, Ailuk, F. S. MacNeil (1 specimen); Taka Atoll, beach, F. S. MacNeil (4 specimens); Ujelang Atoll, sand bar east of Moron Island, F. S. MacNeil (2 specimens); Wotho Atoll, Wotho Island, F. S. MacNeil (88 specimens).

New Caledonia (11 dead tests, the largest 74 by 61 mm.).

Laganum sp.

LOCALITY: Tuamotus, Morrison, 2120 (fragments).

Genus PERONELLA Gray

Peronella lesueuri (L. Agassiz)

Laganum lesueuri L. Agassiz, Monographie des scutelles, p. 116, pl. 24, figs. 3–6, 1841 (southern lands, Péron and Lesueur; also Guadeloupe).

LOCALITY: Okinawa, Shioya, Shanawan, D. Flint, 1947 (1 specimen).

Family *FIBULARIIDAE*

Genus FIBULARIA Lamarck

Fibularia australis Desmoulins

Fibularia australis Desmoulins, Études sur les échinides, p. 240 ,1837 (southern seas).

LOCALITY: Marshall Islands, Wotho Island, F. S. MacNeil (77 specimens).

Fibularia ovulum (Linné)

Echinus ovulum Linné, Systema naturae, ed. 13, vol. 1, pt. 6, p. 3194, No. 83, 1788 (no locality).

LOCALITIES: Marshall Islands, Ujelang Atoll, sand bar east of Moron Island, F. S. MacNeil (39 specimens); Wotho Atoll, F. S. MacNeil (5 specimens).

Genus ECHINOCYAMUS van Phelsum

Echinocyamus megapetalus H. L. Clark

Echinocyamus megapetalus H. L. Clark, Mus. Compar. Zool., Mem. 46(1): 60, pl. 128, figs. 5–8, 1914 (Mauritius).

LOCALITIES: Marshall Islands, Ujelang Atoll, sand bar east of Moron Island, F. S. MacNeil (255 specimens); Wotho Island, F. S. MacNeil (11 specimens).

Family *ECHINONEIDAE*

Genus ECHINONEUS van Phelsum

Echinoneus cyclostomus Leske

Echinoneus cyclostomus Leske, Additamenta ad Jacobi Theodori Klein, p. 173, pl. 37, figs. 4, 5, 1778.

LOCALITIES: Marshall Islands, Kwajalein Atoll, Loi and South Loi Islands, F. S. MacNeil (1 specimen); Likiep Atoll, Nada Island, F. S. MacNeil (1 specimen); Taka Atoll, Taka Island, beach, F. S. MacNeil (8 specimens); Ujae Atoll, Ally Island, F. S. MacNeil (8 specimens); Wotya Island, F. S. MacNeil (1 specimen); Ujelang Atoll, sand bar east of Moron Island, F. S. MacNeil (93 specimens); Wotho Atoll, Wotho Island, F. S. MacNeil (5 specimens).

Tuamotus, Morrison, 1861 (2 specimens); 1883 (1 specimen); 1906 (2 specimens); 1963 (1 specimen).

Family *SPATANGIDAE*

Genus METALIA Gray

Metalia sternalis (Lamarck)

Spatangus sternalis Lamarck, Histoire naturelle des animaux sans vertèbres, vol. 3, p. 31, 1816 (southern oceans).

LOCALITY: New Caledonia (1 specimen).

Metalia spatagus (Linné)

Echinus spatagus Linné, Systema naturae, ed. 10, p. 665, 1758 (oceans everywhere).

LOCALITIES: Guam, Oca Point, David H. Johnson, May, 1945 (1 specimen).

New Caledonia (fragments of a very large specimen bored by a gastropod).

Metalia dicrana H. L. Clark

Metalia dicrana H. L. Clark, Mus. Compar. Zool., Mem. 46(2): 211, pl. 146, fig. 16, pl. 160, figs. 1–4, 1917 (Panglao, Bohol Province, Philippines).

LOCALITY: Marshall Islands, Likiep Atoll, Uado Island, F. S. MacNeil (1 specimen).

Genus MARETIA Gray

Maretia ovata (Leske)

Spatangus ovatus Leske, Additamenta ad Jacobi Theodori Klein, p. 188, pl. 49, figs. 12, 13, 1778.

LOCALITY: Marshall Islands, Uterik, F. S. MacNeil (fragments).

Genus BRISSUS Leske

Brissus latecarinatus (Leske)

Spatangus brissus var. *latecarinatus* Leske, Additamenta ad Jacobi Theodori Klein, pp. XX, 185, 1778.

LOCALITIES: Marshall Islands, Taka Atoll, F. S. MacNeil (2 specimens; the larger, length 123 mm., width 100 mm., height 65 mm.); Ujelang Atoll, sand bar east of Moron Island, F. S. MacNeil (19 specimens; the largest, length 137 mm., width 105 mm., height 78 mm.); Wotho Island, F. S. MacNeil (1 specimen, length 135 mm., width 113 mm., height 81 mm.); no definite locality, F. S. MacNeil (1 specimen).

Class ASTEROIDEA

Family *ARCHASTERIDAE*

Archaster typicus Müller and Troschel

Archaster typicus Müller and Troschel, Preuss. Akad. der Wiss., Monatsber. 1840: 104 (Indian Ocean).

LOCALITY: New Caledonia (3 specimens).

Family *OREASTERIDAE*

Genus PROTOREASTER Döderlein

Protoreaster nodosus (Linné)

Asterias nodosa Linné, Systema naturae, ed. 10, p. 661, 1758 (Indian Ocean).

LOCALITIES: Guam, Oca Point, David H. Johnson, May, 1945 (1 specimen); D. G. Frey, November, 1945 (5 specimens).

Seleo Island, about 5 miles off the northern New Guinea coast at Aitape, about midway between Hollandia and Wewak, coral reef, Capt. Marvin Clinton Meyer (2 specimens).

New Caledonia (3 specimens).

Genus CULCITA L. Agassiz

Culcita novae-guineae

Müller and Troschel

Culcita novae-guineae Müller and Troschel, System der Asteriden, 1842, p. 38 (New Guinea).

LOCALITIES: Marshall Islands, Bikini Atoll, inside pools of outer reef, southeastern Bikini Island, H. S. Ladd, March 23, 1946 (1 specimen); Ailuk, windward reef, F. S. MacNeil, 1951–52 (1 specimen).

Gilbert Islands, Onotoa Atoll, P. E. Cloud, Jr. (1 specimen); G.O.C.–54 (1 specimen).

Tuamotus, Morrison, 2023 (1 specimen); 2059 (1 specimen); 2060 (1 specimen); 2172 (1 specimen).

Guam, Oca Point, David H. Johnson, May, 1945 (4 specimens); D. G. Frey, November, 1945 (5 specimens).

Seleo Island, about 5 miles off the northern coast of New Guinea at Aitape, about midway

between Hollandia and Wewak, Capt. Marvin Clinton Meyer (1 specimen).
New Caledonia (1 specimen).

Family *LINCKIIDAE*

Genus FROMIA Gray

Fromia hemiopla Fisher

Fromia hemiopla Fisher, U. S. Natl. Mus., Proc. 46: 212, 1913 (Tonquil Island, Gumila reef, south of Mindanao, Philippines).

LOCALITIES: Marshall Islands, Ailuk Atoll, near outer edge of seaward reef, leeward side of Ailuk Island, near west end of island, F. S. MacNeil, 1951–52 (1 specimen).
Gilbert Islands, Onotoa Atoll, G.O.C.–36 (3 specimens); G.O.C.–55 (1 specimen).

Fromia milleporella (Lamarck)

Asterias milleporella Lamarck, Histoire naturelle des animaux sans vertèbres, vol. 2, p. 564, 1816 (?seas of Europe).

LOCALITIES: Saipan, lagoon west of the island, P. E. Cloud, Jr., July 4, 1949 (1 specimen).
New Caledonia (1 specimen).

Fromia balansae Perrier

Fromia balansae Perrier, Arch. de Zool. Expt. et Gén. 4: 552, 1875 (New Caledonia).

LOCALITIES: Fiji, Mukuluva reefs, June 12, 1922 (1 specimen).
Samoa, Pago Pago, Vernon L. Kellogg, August, 1902 (3 specimens).

Fromia pacifica H. L. Clark

Fromia pacifica H. L. Clark, Echinoderms of Torres Strait, 1921, p. 42, pl. 31, figs. 5, 6 (Hawaiian Islands).

LOCALITY: Samoa, Pago Pago, Vernon L. Kellogg, August, 1902 (2 specimens).
NOTE: Dr. Clark in the original description recorded this species from the Gilbert Islands.

Fromia monilis Perrier

Fromia monilis Perrier, Arch. de Zool. Expt. et Gén. 4: 443, 1875 (no locality).

LOCALITY: Gilbert Islands, Onotoa Atoll, G.O.C.–36 (2 specimens).
Samoa, Pago Pago, Vernon L. Kellogg, August, 1902 (1 specimen).
No locality (1 specimen).

Genus FERDINA Gray

Ferdina offreti Koehler

Ferdina offreti Koehler, Indian Mus. Asteroidea, p. 143, pl. 16, figs. 2–5, 1910 (Little Andaman, 10 fathoms; Ceylon, 34 fathoms).

LOCALITY: New Caledonia (1 specimen).

Genus GOMOPHIA Gray

Gomophia egyptica Gray

Gomophia egyptica Gray, Ann. and Mag. Nat. Hist. 6: 286, 1840 (Egypt).

LOCALITY: Gilbert Islands, Onotoa, 4–10 feet, Banner, July, 1951 (1 specimen).

Genus NARDOA Gray

Nardoa pauciforis (von Martens)

Linckia pauciforis von Martens, Arch. f. Naturgesch. 32(1): 69, 1866 (Adenare Island, near Flores).

LOCALITY: Solomon Islands, New Georgia, Wilfred G. Iltis (1 specimen).

Nardoa mollis de Loriol

Nardoa mollis de Loriol, Soc. Phys. Nat. Hist. Genève, Mém., Suppl. 8: 26, pl. 3 (12), figs. 4–4f, 1891 (New Britain).

LOCALITY: Seleo Island, about 5 miles off the northern coast of New Guinea at Aitape, about midway between Hollandia and Wewak, Capt. Marvin Clinton Meyer (7 specimens.

Nardoa frianti Koehler

Nardoa frianti Koehler, Indian Mus. Asteroidea, 1910, p. 158, pl. 17, figs. 3, 4 (Andaman Islands, 20 fathoms).

LOCALITY: New Caledonia (1 broken specimen).

Genus OPHIDIASTER L. Agassiz

Ophidiaster granifer Lütken

Ophidiaster granifer Lütken, Vidensk. Meddel. 1871: 276 (Tonga Islands).

LOCALITY: Seleo Island, about 5 miles off the northern New Guinea coast at Aitape, about midway between Hollandia and Wewak, coral reef, Capt. Marvin Clinton Meyer (2 specimens).

Ophidiaster pustulatus (von Martens)

Linckia pustulata von Martens, Arch. f. Naturgesch. 32(1): 62, 1866 (Flores; Amboina).

LOCALITY: Guam, Oco Point, David H. Johnson, May, 1945 (2 specimens).

Ophidiaster perplexus sp. nov.

DESCRIPTION: Rays 5, equal, with parallel sides until near the tip, well arched aborally, flat orally below the marginals; interbrachial angles acute. R = 33 mm., r = 5.5 mm., R = 6r; breadth of arms at base 6 mm.

At the base of the rays on the aboral surface there are three rows of plates between the marginals, but almost immediately additional rows appear by branching of the median row and its successive branches, so that in the outer half of the rays there are seven or eight rows. At the base of the rays all the aboral plates are of about the same size, the marginals only very slightly larger than the others, but on the outer part of the rays, while the plates of the rows adjoining the superomarginals are of about the same size as the latter or only very slightly smaller, those of the inner rows are considerably smaller and more or less irregular in arrangement.

All the plates are completely covered with a continuous coating of very small contiguous spherical granules; a small group of granules on the summit of each plate, or, especially on the marginals, a single granule, are slightly though inconspicuously larger than the others. The aboral and marginal plates are slightly tumid, each longitudinal series forming a low convex ridge, the ridges and the individual plates in the ridges being separated from each other by similar shallow though prominent furrows.

The marginals number about 32; the superomarginals are directly above the inferomarginals, and the plates of the outermost aboral rows are for the most part directly above the superomarginals. The terminal plate is aboral, somewhat flattened-hemispherical, bare, with 4–6 tubercles in an irregular longitudinal series.

In the center of the disc there is a group of about 15 irregularly arranged plates enclosed in a pentagon of 10 subequal larger plates which are broader than long. The radially situated plates in the pentagon are followed by the median row of aboral plates. The plate in this row immediately following the radial plate in the pentagon is somewhat larger than those succeeding, and the next following plate may be slightly enlarged. The interradial plates in the pentagon are separated from the interradial superomarginals by two smaller plates similar to and contiguous with the plates of the lateral rows of the aboral surface between the median row and the superomarginals.

The madreporite, which is about the size of the adjacent interradial plate in the central pentagon, is halfway between the center of the disc and the interradial angle. There is only a single madreporite.

The papulae appear to be single or in small groups of 2 or 3, but are difficult to distinguish between the granules.

On the oral surface of the rays there are at the bases of the rays 4 rows of plates between the adambulacrals and the inferomarginals.

The outermost row extends to about the eighth inferomarginal, and the next disappears in the outer third of the ray. The plates of the oral surface are completely covered with densely crowded small spherical uniform granules resembling those on the aboral surface. The plates are only slightly elevated and are separated by shallow grooves. There appear to be no papulae on the oral surface.

There are no pedicellariae on either the oral or aboral surfaces.

The furrow spines are flattened at right angles to the longitudinal axis of the ray and have broadly rounded tips. Of the two on each adambulacral plate, the adoral is slightly smaller than the aboral. Between the two spines on each plate there are two elongated grains, one above the other, 2 or 3 times as long as broad, the uppermost reaching to the upper third of the spines. These grains are visible only after dissection. On the mouth plates and on a few of the adambulacrals immediately following, grains (usually two) from the oral surface are intercalated between the spines. The outer portion of each adambulacral plate bears a rounded tubercle which is a little larger than the rounded end of the larger spine; this tubercle is separated from the furrow spines by usually two irregular rows of tubercles similar to those covering the oral surface.

The color (dry) is buff white, with small irregular darker blotches.

TYPE: U.S.N.M., E.7999, from pool and pavement zone at the south end of Ngarumaoa Island, Tuamotus; collected by Dr. Joseph P. E. Morrison, September 3, 1952.

REMARKS: *Ophidiaster perplexus* falls within that section of the genus *Ophidiaster* which includes species with granules on the inner surface of the furrow between the furrow spines; with a single madreporite; with few papular pores in each papular area; and with few or no pedicellariae. This group includes only *O. pustulatus* and *O. squameus*, from which *O. perplexus* differs markedly in the arrangement of the plates on the aboral surface; in the fineness and uniformity of the granular covering; in the spherical form of the tubercles on the outer part of the adambulacral plates; and in having the granules on the furrow series double and between pairs of spines instead of between individual spines.

In size and in general appearance *Ophidiaster perplexus* resembles *Linckia multifora* more closely than it does any other species of *Ophidiaster*, and it is possible that in the past it has been confused with it. The rays are slightly stouter than those of *L. multifora*, and the plates on the aboral surface are larger, more tumid, and, at least on the bases of the rays and on the aboral surface of the disc, more regular in arrangement; the papular areas are much smaller, with fewer papulae. On the oral side the armature of the adambulacral plates is strikingly similar, but in *L. multifora* the grains on the inner face of the furrow are between the individual spines instead of between pairs of spines, as in *O. perplexus*. In *L. multifora* there are two madreporites which are much nearer the interbrachial angles than they are to the center of the disc.

Genus LINCKIA Nardo

Linckia multifora (Lamarck)

Asterias multifora Lamarck, Histoire naturelle des animaux sans vertèbres, vol. 2, p. 565, 1816 (?Seas of Europe).

LOCALITIES: Marshall Islands, Eniwetok, Lt. William C. Harrington, July 9, 1944 (1 specimen); Ujae Atoll, soft fine sandy tidal flat at the north end of Ujae Island, F. S. MacNeil, 1951–52 (3 specimens); Uterik Atoll, F. S. MacNeil, November 28, 1951 (3 specimens); Wotho Atoll, Wotho Island, F. S. MacNeil (2 specimens).

Gilbert Islands, Onotoa Atoll, G.O.C.–24 (1 specimen); G.O.C.–36 (3 specimens and 4 comets); G.O.C.–41 (1 specimen); Banner, B–8 (1 comet).

Tuamotus, Morrison, 1884, 1886 (4 specmens); 1860 (46 specimens); 1917 (2 comets);

1920 (1 specimen); 2103 (1 comet); 2121 (4 specimens); 2185 (3 specimens); 2243 (1 comet); 2245 (15 specimens).

Canton Island, L. P. Schultz, June 5, 1939 (1 specimen).

Saipan, lagoon west of the island, P. E. Cloud, Jr., April 27, 1949 (1 specimen); April 27 and May 13, 1949 (5 specimens); May 6, 1949 (1 specimen).

Linckia laevigata (Linné)

Asterias laevigata Linné, Systema naturae, ed. 10, vol. 1, p. 662, No. 8, 1758 (Mediterranean and Indian Seas).

LOCALITIES: Marshall Islands, Bikini Atoll, Bikini Island, from shore (coral head) in Bikini lagoon near Bikini Island, depth 40 feet, J. P. E. Morrison, March 13, 1946 (1 specimen).

Gilbert Islands, Onotoa Atoll, G.O.C.–39 (1 specimen).

Guam, Oca Point, David H. Johnson, May-June, 1945 (16 specimens); D. G. Frey, November, 1945 (2 specimens).

Solomon Islands, New Georgia, Wilfred G. Iltis (5 specimens, one of them 6-rayed).

New Caledonia (1 specimen).

Family *ASTEROPIDAE*

Genus ASTEROPE Müller and Troschel

Asterope carinifera (Lamarck)

Asterias carinifera Lamarck, Histoire naturelle des animaux sans vertèbres, vol. 2, p. 556, 1816 (voyage of Péron and Lesueur).

LOCALITIES: Fiji, Mukuluva reefs (1 specimen).

Guam, Oca Point, David H. Johnson, May, 1945 (1 specimen).

Seleo Island, about 5 miles off the northern coast of New Guinea at Aitape, about midway between Hollandia and Wewak, coral reef, Capt. Marvin Clinton Meyer (1 specimen).

Family *ASTERINIDAE*

Genus ASTERINA Nardo

Asterina cephea (Müller and Troschel)

Asterias cephea (Valenciennes, MS.) Müller and Troschel, System der Asteriden, p. 41, 1842 (Batavia [Djakarta], Java).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–51 (4 specimens, one 4-rayed).

Okinawa, reef off Odomari, A. R. Loeblich, Jr., June 12, 1945 (1 specimen).

Seleo Island, about 5 miles off the northern New Guinea coast at Aitape, about midway between Hollandia and Wewak, coral reef, Capt. Marvin Clinton Meyer (3 specimens).

Genus PATIRIELLA Verrill

Patiriella exigua (Lamarck)

Asterias exigua Lamarck, Histoire naturelle des animaux sans vertèbres, vol. 2, p. 554 (Seas of America, etc.).

LOCALITIES: Admiralty Islands, Manus, D. G. Frey, January 12, 1946 (15 specimens).

Seleo Island, about 5 miles off the northern New Guinea coast at Aitape, about midway between Hollandia and Wewak, coral reef, Capt. Marvin Clinton Meyer (7 specimens).

Genus DISASTERINA Perrier

Disasterina spinulifera H. L. Clark

Disasterina spinulifera H. L. Clark, Mus. Compar. Zool., Mem. 55: 156, pl. 22, fig. 6, 1938 (Broome, Western Australia).

LOCALITY: Saipan, lagoon west of the island, P. E. Cloud, Jr., May 4, 1949 (1 specimen).

Family *ECHINASTERIDAE*

Genus OTHILIA Gray

Othilia luzonica Gray

Othilia luzonica Gray, Ann. and Mag. Nat. Hist. 6: 282, 1840 (Isle of Luzon, Philippines).

LOCALITIES: Marshall Islands, Ailuk Atoll, near outer edge of seaward reef, leeward side of Ailuk Island, near west end of island, F. S. MacNeil, 1951–52 (1 specimen).

Gilbert Islands, Onotoa Atoll, lagoon, A. H. Banner, July, 1951 (1 specimen).

Palmyra Island (2 specimens).

Saipan, lagoon west of the island, P. E. Cloud, Jr., May 13, 1949 (1 specimen).

Family *ACANTHASTERIDAE*

Genus ACANTHASTER Gervais

Acanthaster planci (Linné)

Asterias planci Linné, Systema naturae, ed. 10, p. 823, Appendix, 1758 (Goa [Portuguese India]).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–36 (1 specimen).

Tuamotus, Morrison, 2236 (1 specimen).

New Caledonia (2 specimens).

Class **OPHIUROIDEA**

Family *OPHIACTIDAE*

Genus OPHIACTIS Lütken

Ophiactis savignyi (Müller and Troschel)

Ophiolepis savignyi Müller and Troschel, System der Asteriden, p. 95, Species 12, 1842 (Egypt).

LOCALITIES: Gilbert Islands, Onotoa Atoll, Banner, B–4, in old heads (9 specimens).

Tuamotus, Morrison, 2122 (1 specimen).

Family *OPHIOTRICHIDAE*

Genus OPHIOTHRIX Müller and Troschel

Ophiothrix propinqua Lyman

Ophiothrix propinqua Lyman, Boston Soc. Nat. Hist., Proc. 8: 83, 1861 (Kingsmill [Gilbert] Islands).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–35 (2 specimens); G.O.C.–36 (1 specimen); G.O.C.–51 (3 specimens).

Canton Island, Charles A. Ely, 1942 (1 specimen).

Ophiothrix trilineata Lütken

Ophiothrix trilineata Lütken, Additamenta ad historiam Ophiuridarum, part 3, pp. 58, 100, 1869 (Samoan Islands).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–51 (6 specimens).

Tuamotus, Morrison, 1920 (1 specimen).

Ophiothrix picteti de Loriol

Ophiothrix picteti de Loriol, Rev. Suisse de Zool. 1: 423, pl. 15, figs. 3–3e (Amboina).

LOCALITY: Canton Island, lagoon, in coral, Charles A. Ely, January, 1942 (2 specimens).

Ophiothrix demessa Lyman

Ophiothrix demessa Lyman, Boston Soc. Nat. Hist., Proc. 8: 82, 1861 (Sandwich [Hawaiian] and Gilbert [Kingsmill] Islands).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–30 (2 specimens); exact locality lost, A. H. Banner (1 specimen).

Ophiothrix longipeda (Lamarck)

Ophiura longipeda Lamarck, Histoire naturelle des animaux sans vertèbres, vol. 2, p. 544, 1816 (Mauritius).

LOCALITY: Saipan, lagoon north of Matuis Beach, northwestern Saipan, P. E. Cloud, Jr., December 12, 1948 (1 specimen).

Family *OPHIOCHITONIDAE*

Genus OPHIONEREIS Lütken

Ophionereis porrecta Lyman

Ophionereis porrecta Lyman, Boston Soc. Nat. Hist. Proc. 7: 260, 1860 (?Florida).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–51 (3 specimens).

Saipan, lagoon west of the island, P. E. Cloud, Jr., May 4, 13, 1949 (9 specimens).

Family *OPHIOCOMIDAE*

Genus OPHIOCOMA L. Agassiz

Ophiocoma anaglyptica Ely

Ophiocoma anaglyptica Ely, Wash. Acad. Sci. Jour. 34(11): 373, fig. 1, 1944 (Canton Island, reef).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–30 (1 specimen); G.O.C.–32 (4 specimens).

Ophiocoma scolopendrina (Lamarck)

Ophiura scolopendrina Lamarck, Histoire naturelle des animaux sans vertèbres, vol. 2, p. 544, 1816 (Mauritius).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–41 (2 specimens); G.O.C.–51 (9 specimens); Banner, A–1, A–2 (13 specimens); Banner, exact locality lost (2 specimens).

Tuamotus, Morrison, 1879 (1 specimen); 1994 (1 specimen); 2185 (12 specimens); 2252 (1 specimen); 2254 (2 specimens).

Fiji, Mukuluva reefs, June 12–16, 1922 (26 specimens); reef east of Mukuluva, June 14, 1922 (3 specimens).

Guam, Oca Point, D. G. Frey, November 1945 (2 specimens); January 1946 (2 specimens).

Saipan, lagoon west of the island, P. E. Cloud, Jr., April 19, 1949 (2 specimens).

Solomon Islands, New Georgia, Lt. William A. Bartos, 1944 (2 specimens).

New Guinea, J. E. Hadley (15 specimens).

Ophiocoma erinaceus Müller and Troschel

Ophiocoma erinaceus Müller and Troschel, System der Asteriden, p. 98, 1842 (Red Sea; Indian Ocean).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–24 (8 specimens); G.O.C.–30 (9 specimens); G.O.C.–36 (5 specimens).

Tuamotus, Morrison, 1920 (6 specimens); 2040 (1 specimen).

Saipan, lagoon west of the island, P. E. Cloud, Jr., May 13, 1949 (1 specimen); on Tanapag reef, P. E. Cloud, Jr., April 29, 1949 (3 specimens).

Ophiocoma schoenleinii Müller and Troschel

Ophiocoma schoenleinii Müller and Troschel, System der Asteriden, p. 99, 1842 (India).

LOCALITY: Gilbert Islands, Onotoa Atoll, G.O.C.–41 (2 specimens).

Ophiocoma pica Müller and Troschel

Ophiocoma pica Müller and Troschel, System der Asteriden, p. 101, 1842 (locality unknown).

LOCALITIES: Gilbert Islands, Onotoa Atoll, exact locality lost, Banner (1 specimen).

Tuamotus, Morrison, 1994 (1 specimen).

Ophiocoma brevipes Peters

Ophiocoma brevipes Peters, Preuss. Akad. der Wiss., Ber. 1851: 466 (Mozambique; Querimba Island).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–24 (1 specimen); G.O.C.–30 (1 specimen).

Tuamotus, Morrison, 1920 (1 specimen).

Fiji, Mukuluva reefs (2 specimens).

Netherlands New Guinea, Amsterdam Island, about 5 miles north of Sansapor, Lt. George H. Penn, August 15 to October 3, 1944 (1 specimen).

Ophiocoma sp.

LOCALITY: Gilbert Islands, Onotoa Atoll, G.O.C.–26 (1 specimen).

Genus OPHIOCOMELLA A. H. Clark

Ophiocomella clippertoni A. H. Clark

Ophiocomella clippertoni A. H. Clark, Smithsn. Inst., Misc. Collect. 98(11): 7, pl. 1, figs. 1, 2 (as *O. parva*), 1939 (Clipperton Island).

LOCALITY: Saipan, lagoon west of the island, P. E. Cloud, Jr., May 13, 1949 (4 specimens).

Genus OPHIOMASTIX Müller and Troschel

Ophiomastix mixta Lütken

Ophiomastix mixta Lütken, Additamenta ad historiam Ophiuridarum, pt. 3, pp. 42, 99, 1869 (Samoa and Fiji).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–24 (1 specimen); G.O.C.–36 (1 specimen); G.O.C.–51 (1 specimen).

Saipan, lagoon west of the island, P. E. Cloud, Jr., March 7, 1949 (2 specimens).

Fiji, reef east of Mukuluva, June 14, 1922 (1 specimen).

Ophiomastix bispinosa H. L. Clark

Ophiomastix bispinosa H. L. Clark, Mus. Compar. Zool., Bul. 61(12): 442, pl. 2, figs. 1, 2, 1917 (Paumotu [Tuamotu] Islands, Makemo).

LOCALITY: Gilbert Islands, Onotoa Atoll, Banner, B–1 (1 specimen).

Ophiomastix notabilis H. L. Clark

Ophiomastix notabilis H. L. Clark, Mus. Compar. Zool., Mem. 55: 337, fig. 27, 1938 (Cape Lévêque, Western Australia).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–35 (1 specimen); G.O.C.–51 (2 specimens).

Saipan, lagoon west of the island, P. E. Cloud, Jr., May 13, 1949 (1 specimen).

Ophiomastix annulosa (Lamarck)

Ophiura annulosa Lamarck, Histoire naturelle des animaux sans vertèbres, vol. 2, p. 543, 1816 (from the voyage of Péron and Lesueur).

LOCALITY: Netherlands New Guinea, Amsterdam Island, about 5 miles north of Sansapor, Lt. George H. Penn, August 15 to October 3, 1944 (1 specimen).

Genus OPHIARTHRUM Peters

Ophiarthrum elegans Peters

Ophiarthrum elegans Peters, Preuss. Akad. der Wiss., Ber. 1851: 463 (Querimba Island).

LOCALITIES: Saipan, lagoon west of the island, P. E. Cloud, Jr., May 13, 1949 (1 specimen).

Fiji, Mukuluva reefs, June 8, 1922 (6 specimens).

Ophiarthrum pictum (Müller and Troschel)

Ophiocoma picta Müller and Troschel, System der Asteriden, p. 102, 1842 (Java).

LOCALITY: Guam, Oca Point, D. G. Frey, November, 1945 (2 specimens).

Family *OPHIODERMATIDAE*

Genus OPHIARACHNELLA Ljungman

Ophiarachnella gorgonia (Müller and Troschel)

Ophiarachna gorgonia Müller and Troschel, System der Asteriden, p. 105, 1842 (locality unknown).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–30 (1 specimen).

Guam, Oca Point, D. G. Frey, November, 1945 (1 specimen).

Ophiarachnella infernalis (Müller and Troschel)

Ophiarachna infernalis Müller and Troschel, System der Asteriden, p. 105, 1842 (Indian Ocean).

LOCALITY: Guam, Oca Point, D. G. Frey, November, 1945 (4 specimens).

Genus OPHIOPEZELLA Ljungman

Ophiopezella spinosa (Lungman)

Ophiarachna spinosa Ljungman, Öfvers. K.

Vetensk. Akad. Förhandl., vol. 23, part 6, p. 305, 1867 (Foua).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–30 (1 specimen); G.O.C.–51 (5 specimens).

Saipan, lagoon west of the island, P. E. Cloud, Jr., May 13, 1949 (1 specimen).

Family *OPHIOLEPIDIDAE*

Genus OPHIURA Lamarck

Ophiura kinbergi Ljungman

Ophiura (vel *Ophioglypha*) *kinbergi* Ljungman, Öfvers. K. Vetensk. Akad. Förhandl. 23: 166, 1866 (Sydney, New South Wales, Australia).

LOCALITY: Tuamotus, Morrison, 2124 (1 specimen).

Genus OPHIOLEPIS Müller and Troschel

Ophiolepis cincta Müller and Troschel

Ophiolepis cincta Müller and Troschel, System der Asteriden, p. 90, 1942 (Red Sea).

LOCALITIES: Fiji, Mukuluva reefs (1 specimen).

Saipan, lagoon west of the island, P. E. Cloud, Jr., April 19, 1949 (1 specimen).

Genus OPHIOPLOCUS Lyman

Ophioplocus imbricatus (Müller and Troschel)

Ophiolepis imbricata Müller and Troschel, System der Asteriden, p. 93, 1842 (Mauritius; Timor).

LOCALITIES: Gilbert Islands, Onotoa Atoll, G.O.C.–30 (2 specimens).

Canton Island, reef on the south side under stones, 3–4 feet, Charles A. Ely, October 28, 1941.

Seleo Island, about 5 miles off the northern New Guinea coast at Aitape, about midway between Hollandia and Wewak, Capt. Marvin Clinton Meyer (1 specimen).

ATOLLS AND ISLANDS AT WHICH COLLECTIONS WERE MADE, WITH THE SPECIES COLLECTED AT EACH

ADMIRALTY ISLANDS, Manus: *Patiriella exigua.*

FIJI ISLANDS: *Fromia balansae, Asterope carinifera, Ophiocoma scolopendrina, Ophiocoma brevipes, Ophiomastix mixta, Ophiarthrum elegans, Ophiolepis cincta.*

GILBERT ISLANDS, Onotoa Atoll: *Comaster gracilis, Comantheria polycnemis, Stephanometra indica protectus, Lamprometra palmata palmata, Diadema paucispinum, Echinothrix diadema, Tripneustes gratilla, Parasalenia pöhlii, Echinometra mathaei, Echinostrephus aciculatus, Culcita novae-guineae, Fromia hemiopla, Fromia monilis, Gomophia egyptica, Linckia multifora, Linckia laevigata, Asterina cephea, Othilia luzonica, Acanthaster planci, Ophiactis savignyi, Ophiothrix propinqua, Ophiothrix trilineata, Ophiothrix demessa, Ophionereis porrecta, Ophiocoma anaglyptica, Ophiocoma scolopendrina, Ophiocoma erinaceus, Ophiocoma schoenleinii, Ophiocoma pica, Ophiocoma brevipes, Ophiocoma* sp., *Ophiomastix mixta, Ophiomastix bispinosa, Ophiomastix notabilis, Ophiarachnella gorgonia, Ophiopezella spinosa, Ophioplocus imbricatus.*

HAWAIIAN ISLANDS, Kauai: *Colobocentrotus atratus.*

MARIANA ISLANDS, Guam: *Stephanometra spicata, Eucidaris metularia, Echinothrix diadema, Tripneustes gratilla, Echinometra mathaei, Colobocentrotus mertensi, Heterocentrotus trigonarius, Metalia spatagus, Protoreaster nodosus, Culcita novae-guineae, Ophidiaster pustulatus, Linckia laevigata, Asterope carinifera, Ophiocoma scolopendrina, Ophiarthrum pictum, Ophiarachnella gorgonia, Ophiarachnella infernalis.* Pagan Island: *Colobocentrotus mertensi* [quoted from Nishiyama]. Rota Island: *Comatella maculata.* Saipan: *Echinothrix diadema, Echinometra methaei, Colobocentrotus mertensi, Heterocentrotus mammillatus, Fromia milleporella, Linckia multifora, Disasterina spinulifera, Othilia luzonica, Ophiothrix longipeda, Ophionereis porrecta, Ophiocoma*

scolopendrina, *Ophiocoma erinaceus*, *Ophiocomella clippertoni*, *Ophiomastix mixta*, *Ophiomastix notabilis*, *Ophiarthrum elegans*, *Ophiopezella spinosa*, *Ophiolepis cincta*.

MARSHALL ISLANDS, Ailuk Atoll: *Echinothrix diadema*, *Echinometra mathaei*, *Heterocentrotus trigonarius*, *Laganum depressum*, *Culcita novaeguineae*, *Fromia hemiopla*, *Othilia luzonica*. Arno Atoll: *Comanthus bennettii*, *Comanthus samoana*, *Comanthus parvicirra*. Bikini Atoll: *Culcita novae-guineae*, *Linckia laevigata*. Eniwetok Atoll: *Echinometra mathaei*, *Linckia multifora*. Kwajalein Atoll: *Echinometra mathaei*, *Echinostrephus aciculatus*, *Heterocentrotus trigonarius*, *Echinoneus cyclostomus*. Lae Atoll: *Echinometra mathaei*, *Heterocentrotus trigonarius*. Likiep Atoll: *Heterocentrotus trigonarius*, *Echinoneus cyclostomus*, *Metalia dicrana*. Taka Atoll: *Echinometra mathaei*, *Clypeaster reticulatus*, *Laganum depressum*, *Echinoneus cyclostomus*, *Brissus latecarinatus*. Ujae Atoll: *Echinometra mathaei*, *Echinostrephus aciculatus*, *Clypeaster reticulatus*, *Echinoneus cyclostomus*, *Linckia multifora*. Ujelang Atoll: *Echinometra mathaei*, *Echinostrephus aciculatus*, *Laganum depressum*, *Fibularia ovulum*, *Echinocyamus megapetalus*, *Echinoneus cyclostomus*, *Brissus latecarinatus*. Uterik Atoll: *Echinometra mathaei*, *Heterocentrotus trigonarius*, *Maretia ovata*, *Linckia multifora*. Wotho Atoll: *Heterocentrotus trigonarius*, *Laganum depressum*, *Fibularia australis*, *Fibularia ovulum*, *Echinocyamus megapetalus*, *Echinoneus cyclostomus*, *Brissus latecarinatus*, *Linckia multifora*.

NEW CALEDONIA: *Comanthus bennettii*, *Phyllacanthus imperialis*, *Mespilia globulus*, *Tripneustes gratilla*, *Parasalenia pöhlii*, *Echinometra mathaei*, *Heterocentrotus mammillatus*, *Clypeaster latissimus*, *Laganum depressum*, *Metalia sternalis*, *Metalia spatagus*, *Archaster typicus*, *Protoreaster nodosus*, *Culcita novae-guineae*, *Fromia milleporella*, *Ferdina offreti*, *Nardoa frianti*, *Linckia laevigata*, *Acanthaster planci*.

NEW GUINEA: *Ophiocoma scolopendrina*. Amsterdam Island: *Ophiocoma brevipes*, *Ophiomastix annulosa*. Sansapor: *Echinometra mathaei*. Seleo Island: *Tripneustes gratilla*, *Echinometra mathaei*, *Protoreaster nodosus*, *Culcita novae-guineae*, *Nardoa mollis*, *Ophidiaster granifer*, *Asterope carinifera*, *Asterina cephea*, *Patiriella exigua*, *Ophioplocus imbricatus*.

PALMYRA ISLAND: *Tripneustes gratilla*, *Othilia luzonica*.

PHILIPPINE ISLANDS, Palawan: *Lamprometra palmata plamata*.

PHOENIX ISLANDS, Canton Island: *Heterocentrotus trigonarius*, *Linckia multifora*, *Ophiothrix propinqua*, *Ophiothrix picteti*, *Ophioplocus imbricatus*.

RYUKYU ISLANDS, Okinawa: *Stephanometra indica protectus*, *Echinometra mathaei*, *Peronella lesueuri*, *Asterina cephea*.

SAMOA ISLANDS: *Fromia balansae*, *Fromia pacifica*, *Fromia monilis*.

SAUDI ARABIA, Ras Tanura: *Diadema setosum*.

SOLOMON ISLANDS, Bougainville: *Echinothrix calamaris*, *Tripneustes gratilla*, *Echinometra mathaei*. New Georgia: *Himerometra robustipinna*, *Nardoa pauciforis*, *Linckia laevigata*, *Ophiocoma scolopendrina*.

TUAMOTU ARCHIPELAGO: *Eucidaris metularia*, *Echinothrix diadema*, *Tripneustes gratilla*, *Parasalenia pöhlii*, *Echinometra mathaei*, *Echinometra mathaei* var. *oblonga*, *Colobocentrotus pedifer*, *Heterocentrotus trigonarius*, *Heterocentrotus mammillatus*, *Laganum* sp., *Echinoneus cyclostomus*, *Culcita novae-guineae*, *Ophidiaster perplexus* sp. nov., *Linckia multifora*, *Acanthaster planci*, *Ophiactis savignyi*, *Ophiothrix trilineata*, *Ophiocoma erinaceus*, *Ophiocoma pica*, *Ophiocoma brevipes*, *Ophiura kinbergi*.

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Objective Estimates of Hawaiian Rainfall[1]

CHARLES K. STIDD[2]

THE PROBLEM of interpreting mean weather maps in terms of rainfall has been studied by numerous investigators. Klein (1949), for example, described a method applicable to the Tennessee Valley in winter. The Hawaiian rainfall problem was studied by Solot (1948 and 1950), whose methods have been of some use in estimating expected Hawaiian rainfall from the prognostic maps of the Extended Forecast Section of the U. S. Weather Bureau. While the method, in the hands of a practiced user, probably shows as much skill as the method to be described in this paper, tests (Aubert, MS.) have revealed that Solot's principles may sometimes be interpreted in quite different ways by two different forecasters, which fact points to the need for a completely objective method for making rainfall estimates. One further reason for a new study of the problem at this time is the fact that upper-level data were not readily available to Solot, and his study was based entirely on sea-level pressure patterns. An 18- to 20-year, homogeneous series of mean monthly 700-millibar charts has now been prepared by the Extended Forecast Section, and it has been deemed desirable to develop a method based on this series, since it is the 700-millibar level for which the basic prognosis is made (Namias, 1953).

The present study is a continuation of a former study (Stidd, 1954) in which the correlation field technique was explored, tested, and compared with other methods.

The main purpose of this study is to describe the development of an objective method for interpreting mean weather charts in terms of rainfall, although some attempt is made to supply physical explanations for the relationships revealed by the data.

METHOD

The correlation field technique seems well suited to the problem of relating a parameter in two dimensions (in this case, the height of the 700-mb. surface) to a point parameter (rainfall), since any linear relationships must be revealed and use is made of all data. Furthermore, since no prior knowledge of the relationships is assumed, the method is objective in its development as well as in its application.

To prepare a correlation field pattern for a given rainfall parameter, it is necessary to determine the correlation coefficients between the given rainfall and the 700-millibar heights at each of a number of grid points. These coefficients are then plotted on a base map at the respective grid points, and the pattern is analysed. Such patterns usually are found to be smooth and regular with one or two

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[2] United States Weather Bureau, Washington, D.C.

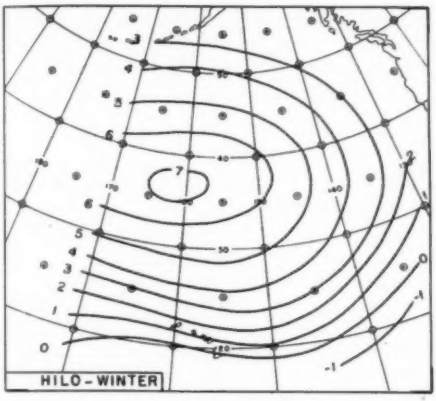

FIG. 1. Correlation field pattern of mean monthly 700-millibar height versus monthly rainfall averaged for four stations in the vicinity of Hilo. Winter months (November through April); total of 102 cases.

well-defined maxima or minima. Little, if any, smoothing is necessary in drawing isopleths to the plotted data. Although space does not allow the data to be shown on these figures, the previous paper (Stidd, 1954, fig. 6) contains the data and demonstrates how little smoothing is needed. An example is given in Figure 1. Here the rainfall parameter is the series of monthly rainfall amounts averaged for four stations in the immediate vicinity of Hilo (see map, Fig. 2). Figure 1 shows that increased pressure north of the islands favors rain at Hilo, and probably indicates that heavy rains are associated with stronger trade-wind gradients and that Hilo rainfall is very sensitive to changes in the trade-wind flow. The actual pattern of Figure 1 is suggestive of the anomalous flow pattern which is associated with heavy rainfall at Hilo. The extent to which this analogy is sound has been described in detail in the previous study (Stidd, 1954), which showed that the regression coefficients of rainfall on pressure fulfill the geostrophic equation in the same manner as the pressures themselves. Furthermore, if there were no spatial variation in the standard deviations of pressure, the correlation coefficients would, themselves, fulfill this equa-

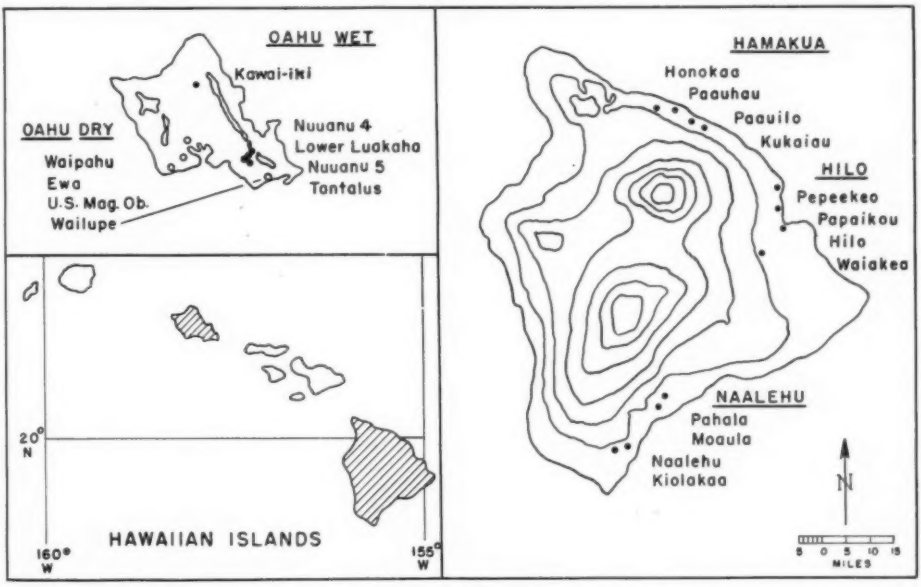

FIG. 2. Map showing location of five groups of rainfall stations in Hawaii. Terrain contours are shown at 2,000-foot intervals.

tion. Thus, it may be said that, disregarding the spatial variations in standard deviation of pressure (or, in this case, 700-mb. height), the correlation field is strictly analogous to an anomalous flow pattern. A tight gradient of the isopleths in the correlation field indicates a strong correlation of the wind tangent to those isopleths. This view of the correlation field is the basis for the discussions of the patterns.

RAINFALL PARAMETERS

Because the rainfall climate varies enormously from point to point within the Hawaiian Islands, no single rainfall parameter will be representative of conditions in general. Stidd and Leopold (1951) showed that two parameters might suffice to describe the rainfall patterns over fairly large areas.

In this study, a group of five stations from the wetter areas of Oahu have been combined to represent one of these parameters, and four dry-area stations represent the other. The combination of the two parameter estimates into an estimate for some other station is explained in the appendix.

Certain areas under the direct influence of mountains higher than 5,000 feet fail to fit into this scheme since their rainfall patterns change systematically with changes in wind direction. In the present study, several such places—Hilo, the Hamakua Coast, and Naalehu—have been tested on an individual basis.

To eliminate some of the randomness found in single-station rainfall data, each rainfall index is composed of the mean of several fairly homogeneous station values. These are listed in Table 1 and shown in Figure 2.

In order to make the rainfall indices have a more nearly normal distribution, the cube roots were taken of all the group rainfall amounts (Stidd, 1953). The assumption that the resulting sets of values are normally distributed is satisfactory in all these cases, as the stations in each group are quite homogeneous and no individual stations reported zero rainfall for any of these months. In some of the 5-day and 1-day data, which are discussed briefly in this report, zeros did occur, but not so frequently as to lead to any serious departures from normal distributions. Seasonal trends were removed by expressing the index value of a given month as a difference from the mean of all the values for that month.

The distribution of 700-millibar heights was assumed to be so nearly normal that no processing was required except for removal of the seasonal trend. This was accomplished in the same manner as for rainfall.

Five-Day Means: These were computed only for the period from November, 1946, through April, 1951. Approximately 255 pairs of values (two overlapping 5-day means per week) were available for each grid point, although, due to the fact of the overlap in 5-day periods and to the fact that serial correlations are higher in 5-day data than in monthly data,

TABLE 1
STATIONS USED IN COMPUTING RAINFALL INDICES

OAHU WET		OAHU DRY		HILO		HAMAKUA		NAALEHU	
Station	Mean annual	Station	Mean annual	Station	Mean annual	Station	Mean annual	Station	Mean annual
Kawai-iki	102.19	Ewa	20.62	Hilo	138.71	Kukaiau	105.56	Naalehu	45.24
Lower Luakaha	137.57	Wailupe	26.11	Papaikou	132.97	Pauuilo	100.81	Kiolakaa	64.46
Tantalus	100.93	Waipahu	25.07	Pepeekeo	128.57	Paauhau	67.91	Moaula Sta.	47.60
Nuuanu 4	141.77	U.S. Mag. Ob.	19.70	Waiakea M.	200.32	Honokaa	93.44	Pahala	43.37
Nuuanu 5	87.59								
Group Mean	112.01		22.90		150.14		92.18		50.17

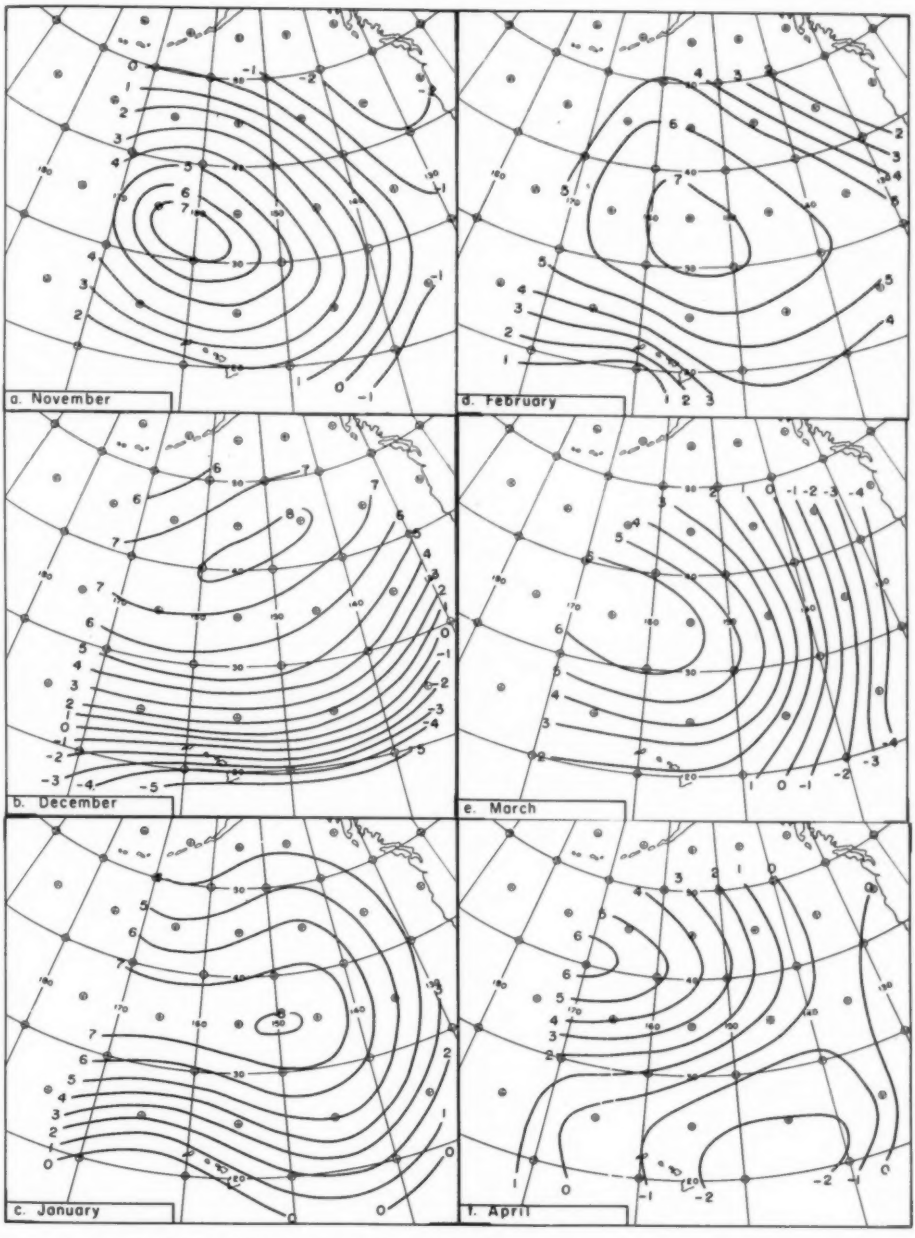

FIG. 3. Data of Figure 1 broken down to show each of the six winter months separately (17 cases in each pattern).

the samples of 5-day data would probably be equivalent to a smaller sample of independent data than would the monthly samples.

Daily Data: For comparison purposes only, daily rainfall amounts were correlated with 700-millibar heights for the months of January and February from 1946 through 1952. Only each fifth day was used, giving 77 pairs of relatively independent data at each grid point. The only rainfall index used was that for Hilo.

HILO (WINTER)

One of the strongest relationships revealed in this study was that between winter-time monthly rainfall at Hilo and the 700-millibar height at 37°N–163°W, in which a correlation of nearly +0.7 was found (Fig. 1). An objective formula based on this coefficient was found to give substantially better results on independent data (see tests) than did the estimates which were made by conventional methods. The correlation coefficient is based on 108 pairs of data, and the temptation is strong to consider it highly significant and meaningful in spite of the fact that the 108 values do not constitute a random sample and that an unknown reduction in degrees of freedom must be considered in view of the possible serial correlation in the data. Since the coefficient in question is merely the best from among many, it must be examined very critically before any significance at all can be attached to it. Chance alone, however, would not give a coefficient this high in random samples of 108 cases once in 10^9 times, and the correlation is undoubtedly significant in spite of serial correlation and its having been selected from among 32 others.

Some evidence of seasonal change in this pattern can be seen in the series of charts shown in Figure 3. Here the winter half-year pattern of Figure 1 is broken down into separate patterns for each of the months. As only 18 pairs of data go into each correlation coefficient shown in this series, the patterns would, by chance, be expected to vary from month to month; however, it is seen that in each case the correlation is quite high at 37°N–163°W.

A physical explanation for the position of this key point is not difficult to provide on the basis of orography, and, as orographic rainfall is of predominant importance to Hilo, this explanation is likely to suffice. The mountains behind Hilo enclose it in an arc which curves gently through approximately 60 degrees. Thus, trade winds ranging in direction from due east to NNE will be captured and lifted rather than deflected around the mountain mass (see map, Fig. 2). It may be supposed, then, that Hilo rainfall will be quite responsive to the strength of the trade winds and that, providing the winds are trades, the precise direction is not particularly important.

In Figure 1 the direction and gradient of the isopleths over Hilo confirm this strong relationship between trade winds and rainfall. The maximum correlation at 37°N–163°W simply indicates the spot where pressure anomalies are most closely related to flow anomalies in the Hilo area. If low latitude data were available, it might be possible to find a center of high negative correlation to the SSW of Hilo.

Since the "strength of the trade winds" is proposed as the physical mechanism between the pressure at 37°N–163°W and rainfall at Hilo, it might be supposed that a more nearly direct measure of trade-wind strength would have a still higher correlation. It is possible to test the gradient directly by correlating the difference in height between two grid points with Hilo rainfall. Such a correlation using the grid points 25°N–145°W and 20°N–140°W gave a coefficient of only 0.38. The discrepancy between the strength of this "direct" correlation and the best coefficient from the correlation field is not easy to understand. It emphasizes once again the difficulty of intuitive selection of parameters, particularly when mean charts and long-range problems are involved.

Figure 4*a* shows a correlation field which associates 5-day mean 700-millibar heights with 5-day rainfall totals at Hilo. It is different from the monthly chart of Figure 1 in three noteworthy respects:

1. The maximum correlation coefficient is much lower.

2. A negative correlation is found in the Hawaiian area.

3. The positive maximum is displaced well to the east of its monthly position.

This chart points up the need for considering the short-period phenomena which go to make up the mean monthly pressure maps and indicates that the reasoning, previously presented to explain the monthly pattern, is not completely adequate. Further evidence for this is provided by Figure 4*b*, which shows the correlation field relating 24-hour rainfall amounts at Hilo to mid-period 700-millibar heights. This chart substantiates Figure 4*a* in showing a negative correlation near Hawaii, but the positive maximum is displaced back to the approximate position which it occupies on the monthly chart. In considering these two shorter-period charts, it should be borne in mind that they include only 5 or 7 years of data and that, in addition, the 24-hour-amounts chart is only for the months of January and February, so that the apparent differences may be due in part to the peculiarities of the particular time periods which the charts represent. The author suspects that this consideration might account for the zonal shift in the positive center but is inadequate to explain the negative correlation in the island area.

The smaller correlation coefficients displayed by the shorter periods are due in part to the larger degree of randomness or "noise" in the basic data. This is largely suppressed in the process of taking 30-day means. In the previous study (Stidd, 1954), short-period data for the Tennessee Valley gave patterns similar to the monthly data, although the strengths of the relationships were reduced in about the same degree as that shown here.

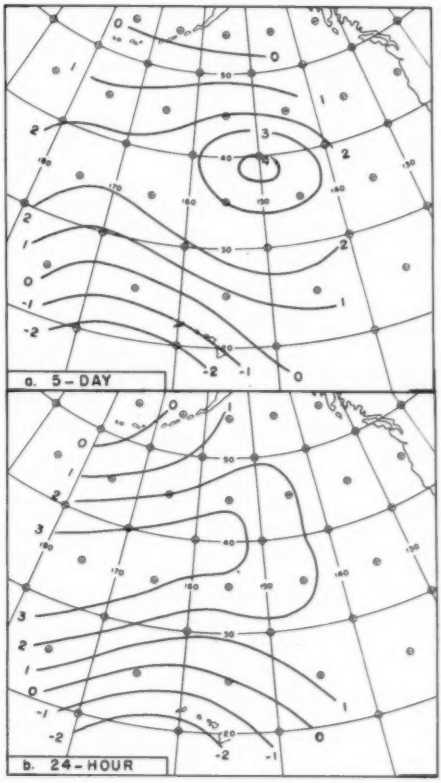

FIG. 4. Correlation field patterns of 700-millibar height versus Hilo area rainfall. *a*, Five-day means, November–April, 255 cases; *b*, twenty-four-hour rainfall amounts and mid-period synoptic 700-millibar heights, data taken every fifth day from the months of January and February, 66 cases.

The Hawaiian short-period patterns, however, are distinctly "different" from the monthly patterns.

It is evident that patterns associated with daily rainfall amounts need not be the same as those for monthly amounts. Suppose that a strong positive relationship exists between pressure at a given point and concurrent rainfall at some other point. During periods when no rain is falling, the pressure at the given point will be low, and in a month's time it might happen that nearly all the days are free of rainfall and marked by low pressure at the

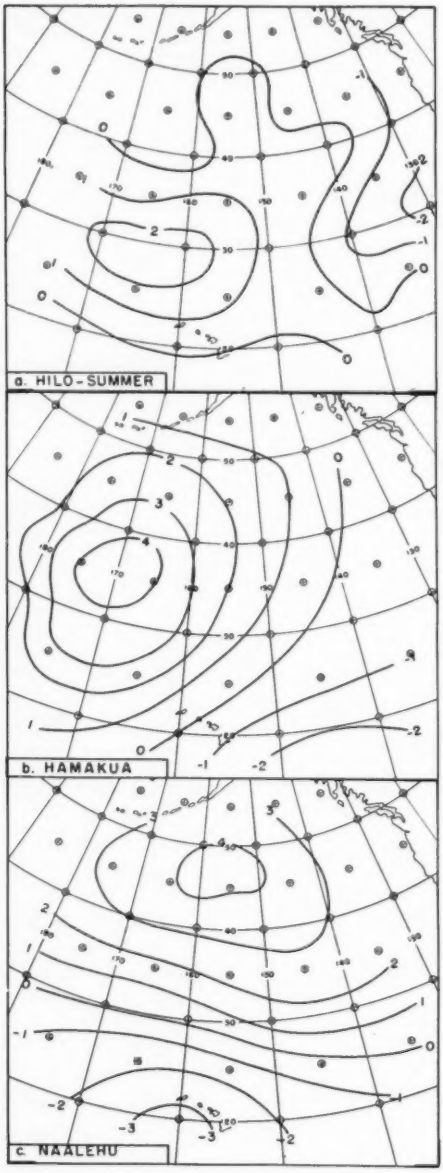

FIG. 5. Correlation field patterns of mean monthly 700-millibar height versus monthly rainfall amounts. *a*, Hilo area, August, 17 cases; *b*, Hamakua Coast, winter months, 102 cases; *c*, Naalehu area, winter months, 102 cases.

given point. In one day's time, however, it is possible for enough rain to fall to yield an above-normal total for the entire month. The high pressure, associated with this one day's rain, would not compensate for the many days of low pressure associated with the drought, and the strong daily relationship would break down on a monthly mean basis. In other words, the problem stems from the fact that there are no "negative amounts" of rainfall to compensate for the few cases of exceptionally heavy rainfall.

Thus, on a mean monthly map the point of maximum correlation may be shifted from the place where it appears on a daily map. The new position may be one at which high pressure favors persistent or repeated periods of rainfall but not, necessarily, concurrent rainfall.

HILO (SUMMER)

Figure 5*a* shows the correlation field of August 700-millibar heights versus Hilo rainfall. The highest correlation on this chart is no more than one would expect to find by chance alone, and it is evident that Hilo summer rainfall has little, if any, linear dependency on the mean monthly 700-millibar chart. This is probably due to the fact that trade winds over Hilo in summer are so deep and steady that their strength cannot be a critical factor and the fluctuations in rainfall must be associated with something other than the fluctuations in trade-wind strength.

This very weak summer relationship is characteristic of all the rainfall indices tested, and thus far no alternative approach to the summer problem has led to very satisfactory long-period objective estimates. These low correlations indicate that Solot's method is likewise inadequate in the summer months.

HAMAKUA

In contrast to the strong relationship shown by the Hilo winter correlation field (Fig. 1) is the much weaker relationship for the Hamakua index (Fig. 5*b*). This rainfall index is

based on the records from a group of gauges spaced along the coast at distances of 27 to 37 miles from Hilo. The slopes behind these stations are convex to the trades, making the precise direction of the trades a more important factor than it is at Hilo. The convexity also has the effect of giving each station a slightly different exposure, with consequent loss in homogeneity.

Smaller mean annual rainfall amounts in this area and greater inhomogeneity among stations suggest that there is more randomness in the Hamakua index than in the Hilo index, and this randomness helps reduce the relationship of the index to the 700-millibar-height field. Comparison of Figure 5*b* with Figure 1 shows that the relationship is reduced to a marked degree, the highest correlation coefficient between Hamakua rainfall and 700-millibar heights being only 0.44.

NAALEHU

Figure 5*c* shows the winter monthly pattern for the Naalehu index. This is a much drier area, responding more to cyclonic activity and less to trade winds than does Hilo. It will be seen to be very similar to the pattern for dry areas on the Island of Oahu, a fact which helps establish the principle that stations having equal mean annual rainfalls respond alike to a given rainfall stimulus.

The high positive center on this pattern is far to the north, presumably the more readily to allow the development of negative values in the immediate vicinity of the Islands. It is unfortunate that data from more southerly latitudes are not available. Experience with patterns of this sort in other areas indicates that the nearby negative center might well be greater in magnitude than the distant positive center. In fact, it is evident in all the patterns that important information could be found in the area south of the Islands.

WET INDEX

Figure 6*a* shows the correlation field pattern associated with the monthly rainfall from

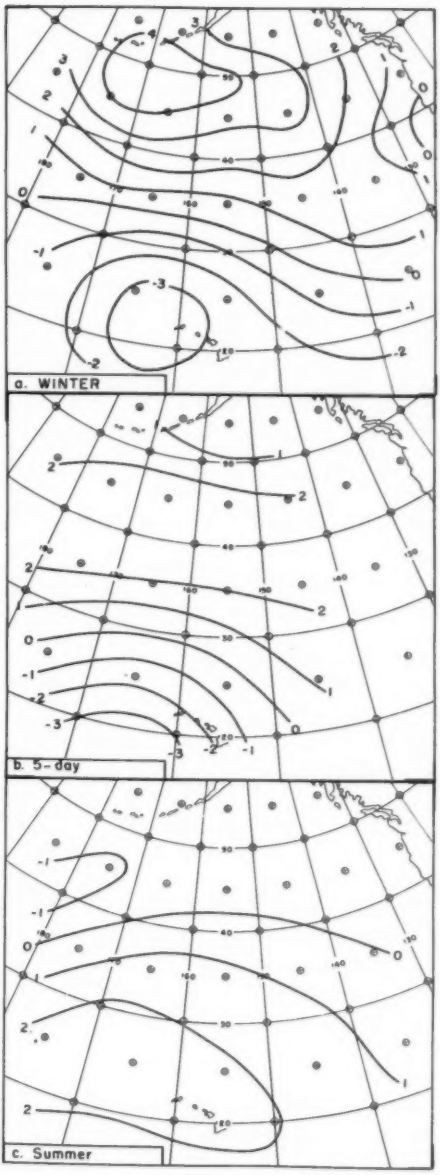

FIG. 6. Correlation field patterns of 700-millibar height versus Oahu wet-index (average of five high-rainfall stations on Island of Oahu). *a*, Monthly amounts, winter, 102 cases; *b*, five-day amounts, winter, 255 cases; *c*, monthly amounts, summer (May through October), 102 cases.

a group of five stations from the wet areas of Oahu. The group mean annual rainfall of 112 inches indicates that these stations derive the bulk of their rainfall from orographic effects, and, as might be expected, the pattern of Figure 6*a* is somewhat similar to that for the Hilo area (Fig. 1). There are three important differences, however, as follows:

1. The positive center is shifted 5 degrees northward.
2. The correlation is negative in the island area.
3. The over-all strength of the relationship is not as great as in the case for Hilo.

The northward shift and negative correlation may indicate a somewhat greater importance of cyclonic activity to the monthly rainfall totals of these wet Oahu stations. The fact that the over-all relationship seems weaker would indicate, as in the case of the Hamakua stations, that rainfall of the wet Oahu stations is not as greatly dependent on the strength of the trade winds as is that of Hilo.

Five-day rainfall amounts for these wet Oahu stations are shown by Figure 6*b* to be more dependent on cyclonic activity and less dependent on the strength of the trades. This is indicated by a negative correlation probably greater than −0.30 just to the southwest of the Islands, a stronger southerly gradient of flow over the Islands, and a much weaker positive belt to the north.

As with Hilo rainfall, summer data fail to reveal any useful relationship between the wet index and the 700-millibar surface. Figure 6*c* shows the pattern for the season May through October.

DRY INDEX

In contrast to the wet-index pattern of Figure 6*a*, Figure 7*a* shows the pattern for a group of four stations chosen from the dry areas of the Island of Oahu. In this pattern the cyclonic origin of the rainfall is emphasized and the similarity of this pattern to that for Naalehu (Fig. 5*c*) is marked. The pattern of Figure 7*b*, 5-day rainfall amounts for the dry-index stations, indicates that the short-period amounts are almost purely dependent on cyclonic activity. The correlation coefficient −0.52 is larger than is usually found with 5-day data.

OBJECTIVE ESTIMATES

In practice it has been found difficult to obtain high multiple correlation coefficients by the combination of several selected points from the 700-millibar chart. In the case of Hilo, for instance, the relationship between the 700-millibar surface and rainfall cannot be boosted, by any significant amount, above the 0.69 expressed by the best simple correlation coefficient in Figure 1. In most other cases, where reasonably high negative correlations are found in addition to the positive center, a combination of two points—those showing greatest positive and greatest negative simple correlation—gives a multiple correlation that is difficult to improve upon by the addition of other points.

Multiple regression equations were developed, by means of which the dry index and the wet index could each be estimated from a knowledge of the heights of two points on the 700-millibar surface. Given the wet and dry indices, rainfall amounts for various stations can be estimated from a knowledge of their mean annual rainfalls. The method has been used in forecasting by applying the regression equations to data from the prognostic monthly mean charts. During the past 2 years, 24 estimates made by the objective method alone had a slightly higher average skill score than the final predictions, which frequently were modifications of the objective estimates.

For those who may wish to apply the method, the regression equations and other essential information are given in an appendix.

COMPARISON TEST

It was mentioned in the introduction that a test had been made on the ability of forecasters to interpret mean charts in terms of

Hawaiian rainfall. This test (Aubert, MS.) covered the period February, 1948, through January, 1950. An experienced long-range forecaster and a meteorologist without much long-range experience worked independently, using observed mean monthly sea-level maps to estimate the rainfall for various Hawaiian stations. They relied heavily on Solot's findings. In order to compare the present method of objective estimates with this test, the 2-year period involved in the test was deleted from the data of the present study, and all the necessary correlations were recomputed. New key points were chosen and the regression constants were altered so that the resulting regression equations were entirely independent of any of the data from the test period.

In that portion of the original test which dealt with winter months, the experienced forecaster had a skill score of 0.25 as against a score of 0.20 for the inexperienced forecaster. The objective method, computed by a statistical clerk, had a skill score of 0.29.

These scores may be interpreted in the usual sense, namely, that they are the correct portion of the group of forecasts which would have been in error had no skill been involved. Without more detailed information they have little meaning in the absolute sense, but they are stated here to indicate relative abilities. Thus, all tests to date seem to indicate that objective methods based on correlation field patterns can do at least as well as the subjective methods of trained forecasters.

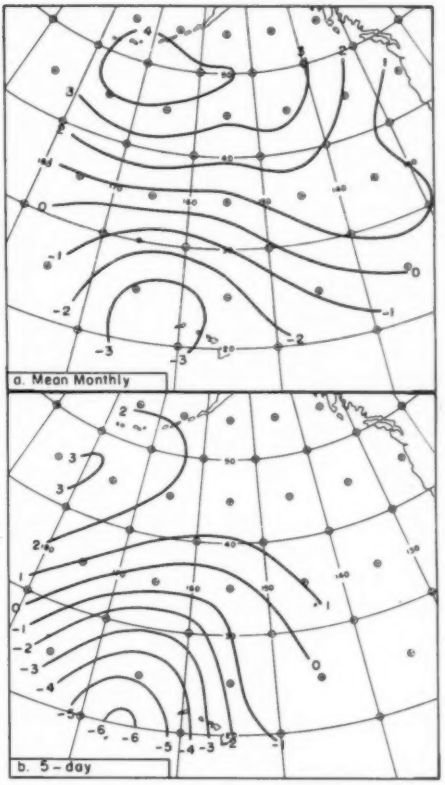

FIG. 7. Correlation field patterns of 700-millibar height versus Oahu dry-index (average of four low-rainfall stations on Island of Oahu). *a*, Monthly amounts, winter, 102 cases; *b*, five-day amounts, winter, 255 cases.

LIMITATIONS OF METHOD

The chief objection to the correlation field method is the fact that only one or two points on the map are considered and all the rest of the map is completely disregarded. As has previously been stated, it does not seem feasible to overcome this objection simply by the addition of more points, because each added point boosts the multiple correlation only very slightly. An alternative approach to the problem would be to attempt to express all the salient features of the map in a few simple terms, using the method of orthogonal polynomials as described by Wadsworth (1948) or the method of spherical harmonics as described by Haurwitz and Craig (1952). This relatively small number of parameters could then be correlated with rainfall and the best ones chosen as predictors. Such an approach tested on data from the United States mainland, showed little improvement over the correlation field method where the key-point correlations were ± 0.6 or higher. Where the correlation fields were weaker than this, however, improvement was indicated.

With regard to the use of only two points, practice seems to indicate that they may be adequate as estimators from an *observed* map but inadequate when used with prognostic charts. This is due to the fact that a prognostic chart may show considerable skill in anticipating the large-scale features of the observed map a month later and yet be in error at the key point or points on which the rainfall forecast is based. Skill scores for Hilo, for instance, have been significantly lower than those for stations on the Islands farther north, and yet the correlation field shows a stronger relationship of the observed 700-millibar chart to Hilo than to any other station.

CONCLUSIONS

Objective long-range estimates of Hawaiian rainfall from observed 700-millibar patterns can be made with a general accuracy at least equal to that attained by a forecaster using conventional methods. The correlation fields shed some light on the mechanisms of mean monthly rainfall processes in Hawaii and suggest limits to our ability to make rainfall estimates from a knowledge of the 700-millibar field.

The use of key points as described in this study comprises a forecast system which is very sensitive to errors on the prognostic charts. It may be possible to overcome this difficulty by the use of orthogonal methods of map description.

Substantial improvement in monthly rainfall forecast accuracy will depend in part on improvement of the prognostic 700-millibar charts and in part on the discovery of rainfall-related factors other than those found in the mean pressure field.

APPENDIX

Regression equations for estimating Hawaiian monthly rainfall amounts from prognostic mean monthly 700-millibar charts. (Height differences are expressed in tens of feet.)

(1) $W = 0.034A - 0.01B$

where W = Oahu—Wet

A = difference from normal 700-mb. height at 42°N–163°W

B = difference from normal 700-mb. height at 20°N–160°W

(2) $D = 0.02C - 0.04E$

where D = Oahu—Dry

C = difference from normal 700-mb. height at 49°N–163°W

E = difference from normal 700-mb. height at 22°N–163°W

When the Oahu-wet and Oahu-dry indices have been computed, an individual station can be estimated as follows:

(3) $t_s = D + \frac{\bar{R}a - 23}{89}(W - D)$

where t_s = the expected standard departure from normal (units of one standard deviation) of the rainfall for a given station, and

$\bar{R}a$ = the mean annual rainfall of the station.

The constants 23 and 89 are, respectively, the rounded mean annual dry-index and wet-index-dry-index differences as determined from Table 1.

Some stations, such as Hilo, which may not fit into the wet- and dry-index system of classification should not be estimated by means of formula 3. The formula used for Hilo is (4) $t_H = 0.04F$

where t_H = the expected standard departure from normal of Hilo rainfall, and

F = the difference from normal 700-mb. height at 37°N – 163°W.

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The Taxonomy of the Salpidae (Tunicata) of the Central Pacific Ocean[1]

JAMES L. YOUNT

INTRODUCTION

KNOWLEDGE OF THE SALPS of the central Pacific Ocean is scanty as heretofore they have been studied only in conjunction with extensive collections, such as those of the "Challenger" and "Albatross" (Herdman, 1888; Metcalf, 1918), from large areas. The present paper, which is limited to a discussion of taxonomy and morphology, is based on large collections that have recently become available. A further report on distribution and ecology is in preparation.

Although much of the present paper is of necessity similar to previously published work, especially those portions describing muscle arrangement, the descriptions are based on original study unless otherwise stated. A new method of study for salps, also applicable to many other planktonic animals, was used and is here described.

Species of the genus *Salpa* were arranged into a number of related subgenera by Metcalf (1918) as follows: *Cyclosalpa*, *Brooksia*, *Apsteinia*, *Salpa*, *Ritteria*, *Thetys*, *Pegea*, *Traustedtia*, *Thalia*, and *Iasis*. Some of these names originated with earlier investigators. Because of prior usage, it was necessary to replace *Ritteria* by *Ritteriella*, and *Apsteinia* by *Ihlea*, which he did in 1919. All these subgenera were raised to the rank of genera by Ihle and Ihle-Landenberg (1933), who at the same time added the genus *Metcalfina* for *Salpa hexagona* Quoy and Gaimard, 1824. This classification is in general use today and is followed here, with the addition of the genera *Helicosalpa* (Todaro, 1902) for *Cyclosalpa virgula* Vogt, 1854, and *C. komaii* Ihle and Ihle-Landenberg, 1936, and *Weelia* gen. nov., for *Salpa cylindrica* Cuvier, 1804. In addition, the subfamilies Cyclosalpinae and Salpinae are newly recognized here.

References included in the specific synonomies are as inclusive as possible since 1912. Additional citations prior to that date are given in detail by Ihle (1912). Only a few of the older reports (previous to 1893) have been examined, thus all citations in the synonymies previous to 1912 have been taken from Ihle unless stated otherwise.

Acknowledgments

Dr. R. W. Hiatt suggested the study and has offered his help whenever needed. I wish to express my thanks for his patient criticism of the investigation in all aspects. I wish also to state my thanks to Dr. L. D. Tuthill who helped solve many problems of a systematic nature and criticized other aspects of the

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study. Especial thanks are due Dr. P. B. van Weel who informed me of the effectiveness of toluidin blue as a stain for salps.

Mr. O. E. Sette, in charge of the Pacific Oceanic Fishery Investigations of the United States Fish and Wildlife Service (referred to in the remainder of this report as POFI), kindly permitted me to use the plankton samples of POFI. In addition, Mr. J. E. King of POFI was helpful in the final judgment as to which plankton samples would be used, as well as in obtaining the samples.

The figure of *Thetys vagina* agg. (Fig. 23*b*) was drawn by Mr. James Park, illustrator of the Department of Zoology and Entomology, University of Hawaii.

MATERIALS AND METHODS

The animals used were taken from a large series of plankton captures made by POFI (principally from cruise 5 of the "Hugh M. Smith"). The area of capture extended from 27°N. to 5°S. and from 176°W. to 155°W.

The animals were studied by staining with toluidin blue. Apparently the idea of staining the animals has not been used by anyone previous to this report except Berner (1954), who used rose bengal.

Salps cannot be advantageously stained in an alcoholic stain, as alcohol dehydrates the test. Some water-soluble stains (such as rose bengal) were found to be rather effective, but they did not result in good differentiation between test and other body structures. P. B. van Weel suggested the use of toluidin blue, which he had used on salps as a vital stain and which, he had found, differentiated between body tissues and test of the living animal. It has proved a most important contribution to this study.

Toluidin blue can be mixed in any water medium, whether it contains formalin, is salty, or is fresh. The dry stain was sprinkled into the fluid until the latter became a deep blue or purple color. The most satisfactory strength is 0.15 gram stain to 500 cubic centimeters water. The animal was placed in the stain from 5 to 30 minutes. While it was in the stain, a small pipette or hypodermic needle was used to inject stain through the mouth or cloacal opening in order to stain body tissues; this is an essential step of the staining process. When body muscles and other internal organs became rather dark, the animal was washed in a vessel containing clear water to remove excess stain. It was then ready for study, best done with a white background, but a black background or even removal from the water may be useful. There are, however, two disadvantages to the use of the stain: (1) it is not permanent in the preservative, and (2) the natural coloration of the animal becomes obscured. The many advantages of the stain, however, greatly outweigh these disadvantages.

Some salps, such as the solitary forms of *C. bakeri*, *C. floridana*, and *H. komaii*, require a different method than the one just described. In the first two species, the muscles are so delicate that they do not stain well at the usual concentration; in the latter species the test absorbs stain heavily, thereby obscuring structures beneath it. The animals were placed in clear water, *not* in the stain. Then a stain of 1 gram to 500 cubic centimeters of water was injected slowly into the body cavity until it was completely filled, and left until the muscles became dark. In this way, the test is not stained, but the body structures are.

Toluidin blue differentiates by staining the test pink and the body tissues varying degrees of blue. Thus the test and various organs of the body become completely visible and yet retain their transparency to a large degree.

Stiasny (1926) reported that the test is useful in combination with other structures, especially muscles, for distinguishing species. However, extensive examination of the stained tests shows that in the aggregate form there is often no basic type of test. It is apparently not as useful as he thought, as I found great variation in test structure of both solitary and aggregate forms.

In many species, the presence of depressions and elevations is entirely accidental, due probably to the convulsive contractions of the muscles at death. In my opinion the presence of elevations and depressions in a soft test (with the exception of distinct ridges and grooves) is in general without value as a character for species determination. There do seem to be a few exceptions, however, i.e., *Pegea confoederata* and *Ritteriella amboinensis* agg.

The asymmetric nature of aggregate individuals of salps is shown not only in the arrangement of muscles, attachment organs, and end projections but also in the sculpture of the test when it is stiff and has permanent structures (Stiasny, 1926; Ihle, 1937–39).

In some species, such as *Thalia democratica*, there are two basic body forms: one has a relatively thick test, prominent ridges and grooves, and wide muscle bands; the other has a thin test, ridges weak or absent, nonpermanent elevations and depressions, and narrow muscles.

Van Beneden and de Selys-Longchamps (1913) (*fide* Stiasny, 1926) and Stiasny showed that there had been entirely too much reliance on muscle arrangement for differentiating the various species. Nevertheless, muscle arrangement is one of the most important recognition features. In order to determine some species, however, it must be combined with other features.

MORPHOLOGY

With the exception of Traustedt (1885), Brooks (1893), van Beneden and de Selys-Longchamps (1913) (*fide* Brien, 1948), and Stiasny (1919, 1926), all investigators have described the test only incidentally, their work being primarily concerned with the muscular arrangements of the various species. The only considerable contribution to the knowledge of test structure was made by Stiasny (1926). As he showed, the great difficulty encountered in the study of the test is its almost complete agreement in refractive index with water. Some salps have tests with ridges and grooves that can be seen under water, but the test of most shows little or no opacity. Hence, almost all investigators have completely disregarded the test in their researches. Traustedt (1885) and Brooks (1893) described the test in a few species, and Brooks recognized a basic plan in the test that fits some salps, especially the solitary forms. This plan was named Brooks' rule (Regel von Brooks) by Stiasny (1926), and he applied it to many forms. Stiasny also clarified the rule and stated it as follows:

> . . . finden wir regelmässig in der Mitte der Dorsalseite eine (tiefe) Längsfurche, beiderseits begrenzt von vorspringenden kiel-ännlichen Kanten, an den seiten des Mantels vorspringende scharfe Kanten oder Flügelartige Verbreiterungen; auf der Ventralseite ist die Testa dick, mit einem medianen und 2 lateralen Kielen.

Stiasny also set up a scheme of nomenclature for test structure which is followed here although some of his terms have been changed. The result is a combination of his terms, of those used by Delage and Hérouard (1898), and some additions. It is believed that the terminology used here is both clearer in meaning and easier for use in descriptions. The resulting scheme is shown in Figure 1.

The following terms are used to describe the test:

test—the outer tunic or covering over the epidermis
mantle—the epidermis and associated tissues; the term does not refer to the test
ridge—a distinct elongate bulge, triangular in cross section
groove—a distinct elongate, angular invagination
elevation—a rounded, elongate bulge
depression—a rounded, elongate invagination
swelling—a prominent, nonelongate, rounded bulge
cavity—any concavity of the internal surface of the test

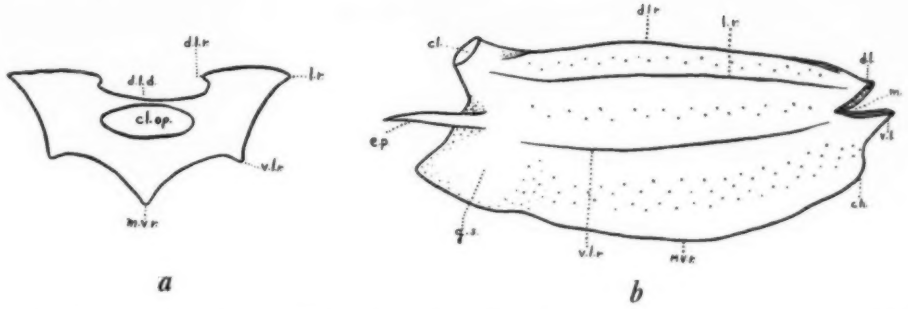

FIG. 1. Scheme of the test of a solitary form. *a*, End aspect (after Stiasny, 1926); *b*, lateral aspect (modified after Delage and Hérouard, 1898). *ch*, Chin; *cl*, cloacal opening; *dl*, dorsal lip; *dld*, dorsal longitudinal depression; *dlr*, dorsal limiting ridge; *ep*, end projections; *gs*, gut swelling; *lr*, lateral ridge; *m*, mouth; *mvr*, midventral ridge; *vl*, ventral lip; *vlr*, ventrolateral ridge.

chin—the swelling on the ventral anterior surface below the ventral lip

spine—a small, conical protrusion beyond the test margin

projection—a large protrusion of the test; it is never filamentous but may contain a mantle projection

tentacle—a filamentous protrusion of the test; it usually contains a mantle projection

sucker—a disc-like enlargement at the end of the mantle (epithelial) tube in the projections of some forms (e.g., *Thalia democratica*, sol.)

Furthermore, when the terms "ridge," "groove," etc., are used, they always refer to longitudinal ridges and grooves unless stated otherwise.

The general morphology of salps is schematized in Figure 2 to identify structures in the remaining figures. Body muscles are designated by Roman numerals from anterior to posterior (M III = body muscle three), whereas mouth and cloacal muscles are designated by letters (A, B, C, and x, y, z, respectively). This notation follows that set up by Streiff (1908) as used by Ihle (1935, 1937–39), except cloacal muscles are denoted by lowercase letters to avoid confusion with body muscles.

In addition to those listed in Figures 1 and 2, the following abbreviations are used in the other figures: *ant*, Anterior; *bl.f*, blood-forming organ; *bm*, "baumförmiger Fortsätze"; *bv*, blood vessel; *cir.pr*, circular projection; *cl.fl*, cloacal flap; *cr*, crest (dorsal limiting ridge); *dle*, dorsal limiting elevation; *dlp*, dorsolateral projection (atrial palp); *d.ten*, dorsal tentacle; *el.c*, elaeoblast cavity; *em*, embryo; *f*, fold in bottom of pharynx; *hft*, attachment organ; *ho*, hook; *in*, independent muscle; *lo*, light organ; *lpp*, lateral posterior projection; *mdr*, middorsal ridge; *mvp*, midventral projection; *ob.gr*, oblique groove; *ob.r*, oblique ridge; *pa*, test patch; *ped*, peduncle; *pl.pr*, posterolateral projection (tentacle); *pr*, posterior ridge; R, right side; *rec*, rectum; *sn*, snout; *st.at*, attachment organ; *st.op*, opening for stolon; *tes*, testis; *tr.d*, transverse depression; *vle*, ventrolateral elevation; *vlp*, ventrolateral projection; *vr*, ventral ridge.

Most drawings in this paper do not show oral or cloacal muscles, as these are small and difficult to place correctly in a drawing of the whole animal. They are described and figured for most species by Streiff (1908), Metcalf (1918), Ihle (1935, 1937–39), and Thompson (1948).

It is probable that further study will show that the attachment organs are of considerable taxonomic importance. They are only incidentally described in this paper.

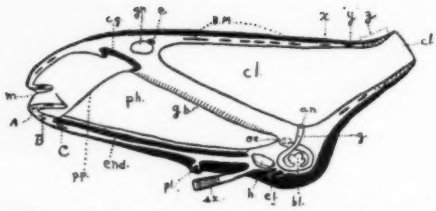

FIG. 2. Schematic median section of a solitary salp (after Ihle, 1935). A, Velum muscle; *an*, anus; B, lip muscle; *bl*, blind sac (caecum of gut); BM, body muscles; C, bow (intermediate) muscle; *cg*, ciliated groove (dorsal tubercle); *cl*, cloaca and its opening; *e*, eye; *el*, elaeoblast; *end*, endostyle; *g*, gut (intestine); *gb*, gill bar; *gn*, ganglion; *h*, heart; *m*, mouth; *oe*, esophagus; *ph*, pharynx; *pl*, placenta; *pp*, peripharyngeal band; *st*, stolon; *x*, first cloacal muscle; *y*, second cloacal muscle; *z*, third cloacal muscle (composed of a series of small sphincters).

KEY TO WORLD SPECIES AND REPRODUCTIVE FORMS OF SALPIDAE

1. Gonads present; stolon absent; eggs or embryos usually present.....aggregate (gregarious) form.....2

   Gonads absent; stolon usually present; eggs and embryos absent.....solitary (oozooid, asexual) form.....22

2(1). Intestine straight, anteriorly directed; one light organ present laterally between M II–III (there may be another between M III–IV).....**Cyclosalpa pinnata**

   Intestine neither straight nor anteriorly directed; no light organ present.....3

3(2). Two posterior projections present, containing testis and a caecum, respectively.....**Cyclosalpa bakeri**

   One or no posterior projection present.4

4(3). Testis spherical.**Helicosalpa komaii**

   Testis not spherical.....5

5(4). Posterior appendage containing testis present.....6

   Posterior appendage containing testis not present.....7

6(5). Testis projects dorsolaterally within posterior test projection.....**Helicosalpa virgula**

   Testis projects ventroposteriorly within posterior swelling.....**Cyclosalpa floridana**

7(5). Gut forms a broad loop with central space empty; a peduncle present.....**Cyclosalpa affinis**

   Gut either tightly looped or with central space filled; peduncle absent.....8

8(7). Some body muscles form complete rings.....9

   No body muscles form complete rings.....10

9(8). Body muscles fused into a single unit dorsally and ventrally.....**Brooksia rostrata**

   Body muscles not fused into a single dorsal and ventral unit; however, M II and III are rings...**Ihlea magalhanica**

10(8). All body muscles interrupted dorsally.....**Thetys vagina**

   Some or all body muscles continuous dorsally.....11

11(10). M I interrupted dorsally.....**Iasis zonaria**

   M I continuous dorsally.....12

12(11). Four symmetrical attachment organs project from each side of body.....**Pegea confoederata**

   Attachment organs either asymmetrical or not projecting beyond test outline.13

13(12). One elongate tentacle projects posteriorly from each lateroposterior angle of body.**Traustedtia multitentaculata**

   No elongate tentacle as above (short attachment organs may project laterally from the posterior region of *Thalia democratica* agg.).....14

14(13). Ventral lip sphincter 4(Mb_3) interrupted.....**Salpa fusiformis**

   Ventral lip sphincter 4 continuous, if present.....15

15(14). Muscles arranged in groups of 3 and 2 dorsally.....16

Muscles arranged in groups of 4 and 2, 4 only or 2 only dorsally 18

16(15). Gut within a broad pointed or rounded median posterior projection; ciliated groove bears a ventral languet 17

Posterior projection not containing gut; ciliated groove without languet . . . . . **Weelia cylindrica**

17(16). M III is formed of 8 or 9 fibers (Apstein, 1906*a*) . . **Thalia longicauda**

M III is formed of 3 fibers (Apstein, 1906*a*) . . . . . **Thalia democratica**

18(15). M II extends beyond endostyle to between M V–VI of opposite side . . . . . **Ihlea punctata**

M II not as above 19

19(18). Posterior projection extends beyond cloacal opening 20

Posterior projection does not extend beyond cloacal opening . . . . . **Metcalfina hexagona**

20(19). Independent muscle small, inconspicuous; M I–II narrowly fused dorsally; spaces between transverse ribs of gill bar less than 0.5 width of bar . . . . . **Salpa maxima**

Independent muscle large, conspicuous; M I–II widely fused dorsally; spaces between transverse ribs of gill bar greater than 0.5 width of bar 21

21(20). Dorsal lip sphincter 1 (M A_1) interrupted middorsally . . . . . **Ritteriella picteti**

Dorsal lip sphincter 1 continuous middorsally . . . . . **Ritteriella amboinensis**

22(1). Intestine accompanies gill bar 23

Intestine does not accompany gill bar 28

23(22). Ventral longitudinal muscle present 24

Ventral longitudinal muscle absent . . 25

24(23). A single dorsal longitudinal muscle present, connecting M I with M x on each side . . . . . **Helicosalpa komaii**

Two dorsal longitudinal muscles present, connecting M I with M VI on each side . . . . . **Helicosalpa virgula**

25(23). M I–IV fused ventrally into a single mass . . . . . **Cyclosalpa floridana**

M I–IV not fused ventrally 26

26(25). Three to five light organs present on each side of body 27

Not more than one light organ present on each side of body . **Cyclosalpa affinis**

27(26). M VI forming 2 anteriorly directed dorsal longitudinal muscles . . . . . **Cyclosalpa bakeri**

M VI forming one fused, anteriorly directed dorsal longitudinal muscle, or none . . . . . **Cyclosalpa pinnata**

28(22). A muscular snout projects anteriorly beyond mouth opening . . . . . **Brooksia rostrata**

No muscular snout projects anteriorly 29

29(28). Body muscles interrupted dorsally 30

Body muscles continuous dorsally . . 31

30(29). A long projection extending posteriorly from both posterolateral angles of body; test spiny . . . . . **Thetys vagina**

No such projections present; test smooth . . . . . **Iasis zonaria**

31(29). Some body muscles form complete rings 32

All body muscles interrupted ventrally 36

32(31). Longitudinal muscles present on each side of body, internal to body muscles . . . . . **Ihlea punctata**

Longitudinal muscles absent 33

33(32). A long projection extending posteriorly from each posterolateral surface of body 34

No such projections present 35

34(33). M I–III and IV–V forming groups dorsally . . . . . **Thalia democratica**

All body muscles separate, parallel (Traustedt, 1885) ..... **Thalia longicauda**

35(33). Not more than first four body muscles forming complete rings ..... **Ritteriella amboinensis**

M I–VI forming complete rings (Thompson, 1948) ..... **Ihlea magalhanica**

36(31). Intestine straight, extended posteriorly ..... **Ritteriella picteti**

Intestine coiled, not extended 37

37(36). Projections of test or tentacles extending beyond body outline 38

No projections of test extending beyond body outline 39

38(37). Two posterior projections present; 9 to 13 body muscles present, asymmetrical ..... **Metcalfina hexagona**

No posterior projections but with two to many tentacles; body muscles few (5), symmetrical ..... **Traustedtia multitentaculata**

39(37). Four body muscles present ..... **Pegea confoederata**

More than 4 body muscles present .. 40

40(39). Elaeoblast or its cavity present in mature specimens; ciliated groove forming a loop ..... **Salpa maxima**

Elaeoblast present only in embryos; ciliated groove simple in immature specimens 41

41(40). M I–IV converging to form a group ..... **Weelia cylindrica**

M I–III and VIII–x converging, or are parallel ..... **Salpa fusiformis**

Family SALPIDAE

The definition of the family by Ihle (1935) is followed here chiefly.

Planktonic Thaliacea with main body axis longitudinal, covered with a transparent test. Mouth opening anterior, cloacal opening posterior, dorsal or terminal. Body musculature consists of usually ventrally interrupted muscles but may include complete rings or dorsally interrupted muscles as well. Special mouth and cloacal musculature present. Pharyngeal and cloacal cavities separated by a "gill bar" lying between two large gill slits; gill bar extending from anterodorsal surface to esophagus located posteroventrally. An alternation of generations exists between the sexual blastozooid (aggregate or gregarious form) and the asexual oozooid (solitary form). The oozooid bears ventrally a proliferating stolon on which the blastozooids arise. The blastozooid produces one or several embryos on the cloacal wall which become oozooids.

The family Salpidae consists of two distinct groups of genera. I propose to give these groups the status of subfamily: the Cyclosalpinae including *Cyclosalpa* and *Helicosalpa*, the former being the type genus, and the Salpinae including all other genera of the Salpidae, *Salpa* being the type genus.

CYCLOSALPINAE subfam. nov.

The subfamily Cyclosalpinae may be distinguished by the following characteristics: (1) in the solitary form, the intestine accompanies the gill forward, being united with it over most of its length; (2) there are light organs present in all solitary forms except *C. affinis*, and here one is probably present (see description); (3) in the aggregate form, the gut is either an extended tube or a loosely formed loop, never a compact "nucleus"; (4) the aggretate forms are attached by a single peduncle or by a single large attachment process.

Genus CYCLOSALPA Blainville, 1827

Solitary form with six body muscles, gregarious form with four. In the solitary formt longitudinal muscles absent or, if present, no, continuous with M I. Intestine coursing obliquely with gill bar in the solitary form, but not forming a rectum. Intestine either straight or forming an open circle in the aggregate form. Only one attachment organ, the pe-

duncle, present in the aggregate form. Body muscles penetrating into peduncle. Groups of blastozooids forming whorls on stolon.

Four species: *Cyclosalpa pinnata* (type), *C. affinis*, *C. floridana*, and *C. bakeri*.

Cyclosalpa pinnata (Forskål) 1775
Fig. 3*a–d*

Salpa pinnata Forskål, 1775: 113.
Biphora pinnata Bruguiére, 1789: 180.
Salpa pelasgica [?] Bosc, 1802: 181.
Salpa cristata Cuvier, 1804: 366.
Salpa thalia [?] Lamarck, 1816: 119.
Salpa caudata [?] Lamarck, 1816: 119.
Salpa (*Cyclosalpa*) *pinnata* Blainville, 1827: 108; Metcalf, 1918: 9; Sewell, 1926: 68; Stiasny, 1926: 414.
Salpa cyanea [?] Chiaje, 1828: 63.
Salpa proboscidalis Lesson, 1830: 95.
Salpa mucosa [?] Costa, 1839: 225.
Orthocoela pinnata Macdonald, 1864: 181.
Cyclosalpa pinnata Herdman, 1888: 87; Ihle, 1935: 527–529; Tokioka, 1937: 219; Thompson, 1948: 103.
Cyclosalpa polae Sigl, 1912*a:* 66; 1912*b* (*fide* Ihle and Ihle-Landenberg, 1937); Fedele, 1926, 1933 (*fide* Ihle and Ihle-Landenberg, 1937); Ihle and Ihle-Landenberg, 1937: 1.
Cyclosalpa bakeri Bomford, 1913: 243.
[non] *Cyclosalpa bakeri* Ritter, 1905: 54.
Salpa (*Cyclosalpa*) *pinnata polae* Metcalf, 1918: 26; Sewell, 1926: 68; Komai, 1932: 69.
Cyclosalpa pinnata polae Ihle, 1935: 527–529.
Cyclosalpa pinnata var. *polae* Tokioka, 1937: 220.

SOLITARY FORM: Four specimens examined with length range of 4–12 mm. (Fig. 3*c,d*). *Test:* Rather thin, glutinous, without definite elevations or depressions. Median dorsal ridge described by Stiasny (1926) absent as are anterior "ventral languets" shown by Metcalf (1918). *Muscles:* Six body muscles, each interrupted dorsally and ventrally; oral muscles touching M I. *Ciliated groove:* An arched U in dorsal view, but may be sinuous or convoluted according to various investigators.

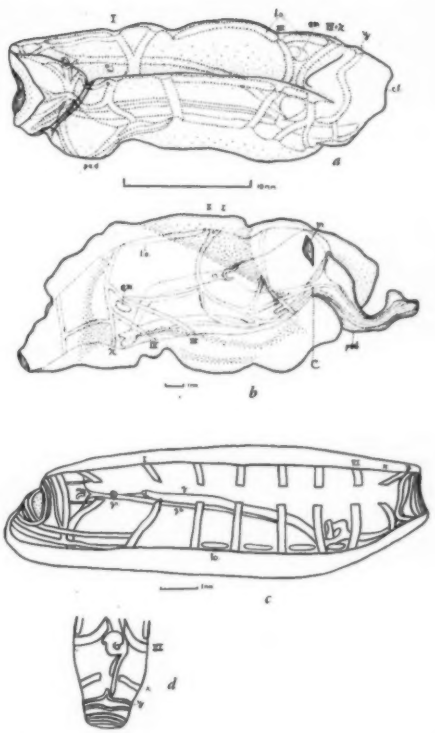

FIG. 3. *Cyclosalpa pinnata*. *a*, Aggregate form, left dorsal side; *b*, aggregate form, right dorsal side; *c*, solitary form, left side; *d*, solitary form, ventral view of cloacal region.

Viscera: Esophagus opening between M VI and x on right side, connecting to intestine which accompanies gill antero-obliquely; at junction of intestine and esophagus, two caeca projecting posteriorly, the left one almost twice the length of the right one; light organs four on each side, between muscle bands II–x (five according to most investigators, but Sewell, 1926, found only four—none between I–II—and this is also true of POFI specimens).

AGGREGATE FORM: Four specimens examined with length range of 11–31 mm. (Fig. 3*a,b*). *Test:* Thin and flabby, far separated from mantle except at region of mouth and cloacal openings; glutinous; no definite

elevations or depressions; peduncle long in small (*C. p. polae?*) specimens (Fig. 3*b*), much shorter in largest specimen (Fig. 3*a*). *Muscles:* Four body muscles; M I–II fused dorsally, III, IV, and x approaching or fusing dorsally; mouth muscles joining M I; bow muscles (C) forming anterior peduncle muscles on each side, M I and II fusing ventrolaterally to form posterior peduncle muscles. Thus, a total of four peduncle muscles present. *Ciliated groove:* Simple or U-shaped, located vertically. *Viscera:* Esophagus opening at level of junction of M III–IV–x; a single, posteriorly directed caecum, intestine coursing anteriorly beneath endostyle, anus opening at region of M II–III, but in larger specimen at region of M I; testis prominent, longitudinally plicated, arising at junction of esophagus and intestine, accompanying intestine anteriorly, opening by small duct slightly posterior to anus; embryo near M III or between M III–IV dorsally; one light organ on each side between M II and III—there may be two, as shown in Fig. 3*a* and as shown by Ihle (1910), Komai (1932), and Tokioka (1937); examples previously described with two pairs of light organs, as the present specimen, always large (length of specimen, 28 mm.), so this condition probably due to age.

The form (species, subspecies, variety) *polae* has been distinguished from *C. pinnata* chiefly by the following characteristics in the gregarious form (Ihle and Ihle-Landenberg, 1937); length of body, length of peduncle, relationships of M III and IV dorsally, shape of ciliated groove, eye, caecum (blind sac), and position of anus. There are evidences, however, chiefly from Sewell (1926), that this form is not distinct from *C. pinnata*. The separation dorsally of M III and IV is found in *C. pinnata* as well as in animals fitting the description of *C. polae* (Metcalf, 1918; Sewell, 1926; Komai, 1932). The ciliated groove intergrades between the form *polae* and the type (Sewell, 1926). The solitary form of *C. polae* is distinguished (Sigl, 1912*a*) by the middorsal fusion of the two M VI and their continuance as a band forward. This character apparently intergrades but should receive further study. Sewell (1926) stated:

> Had I been dealing solely with examples of the aggregated zooid I should have had no hesitation in referring this form to the subspecies *polae* but, as I have already shown, the asexual generation [of the Indian form] must be referred to *C. pinnata.* It is impossible, therefore, to distinguish *Cyclosalpa polae* from *C. pinnata* even as a sub-species, and much less, as Sigl originally claimed, as a species.

Ihle and Ihle-Landenberg (1937), however, critically studied specimens of the aggregate zooid of both forms and concluded that the two forms should be considered distinct species, as Sigl (1912*a*) had regarded them.

I have had only typical specimens of the solitary zooid of *C. pinnata* and thus can add nothing which might help settle this problem. The aggregate zooids of the POFI collections, however, show intergradation in the dorsal separation of M III–IV and structure of the ciliated groove. Tentatively, I follow Thompson (1948) in regarding the form *polae* as simply showing differences attributable to changes occurring with increasing size and believe that its recognition as a subspecies or species is probably not justified. Doubtless, the answer to the problem lies in a study of various-sized solitary forms.

An embryo was found in a collection containing aggregate forms that fit the description of *C. polae* (Fig. 3*b*). This embryo, however, is evidently a typical *C. pinnata* as the two M VI do not fuse dorsally. It was not attached to its mother, so I cannot relate it directly to the form *polae*.

Cyclosalpa affinis (Chamisso) 1819
Fig. 4 *a*, *b*

Salpa affinis Chamisso, 1819: 11.

Cyclosalpa affinis Blainville, 1827 [*fide* Ritter, 1905]; Ihle, 1935: 527–529; Tokioka, 1937: 221; Thompson 1948: 108.

Salpa pinnata var. [?]Quoy and Gaimard, 1834: 582.

Salpa chamissonis Brooks, 1893: 376.
Salpa (*Cyclosalpa*) *affinis* Apstein, 1894*b:* 4; Metcalf, 1918: 27; Sewell, 1926: 74; Komai, 1932: 70.

SOLITARY FORM: One specimen examined with length of 54 mm. (Fig. 4*a*). *Test:* Thin, glutinous, attached at mouth and cloacal opening; no definite elevations or depressions. *Muscles:* Six body muscles: M I and II interrupted dorsally and ventrally, M III–VI interrupted ventrally, continuous dorsally; x sending one branch anteriorly (broken in this specimen) which is continuous with posterior branch of M VI; x continuing far ventrally; x and y converging laterally but not touching; M I joining mouth muscles. *Ciliated groove, ganglion and eye:* Ganglion and eye anterior to M I, just above anus; ciliated groove far anterior to them, highly convoluted. *Viscera:* Esophagus forming a spiral at ventral level of M VI and x; a single posterior caecum (actually double, appearing single, according to Komai, 1932) connecting to intestine which courses antero-obliquely with gill; anus opening just anterior to M I; gill ending anterior to M C; a large oval body located on each side between M IV and V. It is conspicuous with stain and probably is a light organ (this is not mentioned in past descriptions).

AGGREGATE FORM: Three specimens examined with length range of 18–33 mm. (Fig. 4*b*). *Test:* Closely attached at mouth, cloacal opening, on peduncle and intestine (Metcalf, 1918, figures it as very loose on latter two structures); test with no definite elevations or depressions, glutinous, thin, may be far separated from mantle; peduncle short, broad. *Muscles:* Four body muscles; all interrupted ventrally, continuous dorsally and separated from one another except IV and x; M I joining with mouth muscles; M C forming anterior peduncle muscles, posterior peduncle muscles independent; total of four muscles in peduncle, two anterior and two posterior; M I sending off two anterior branches; x and

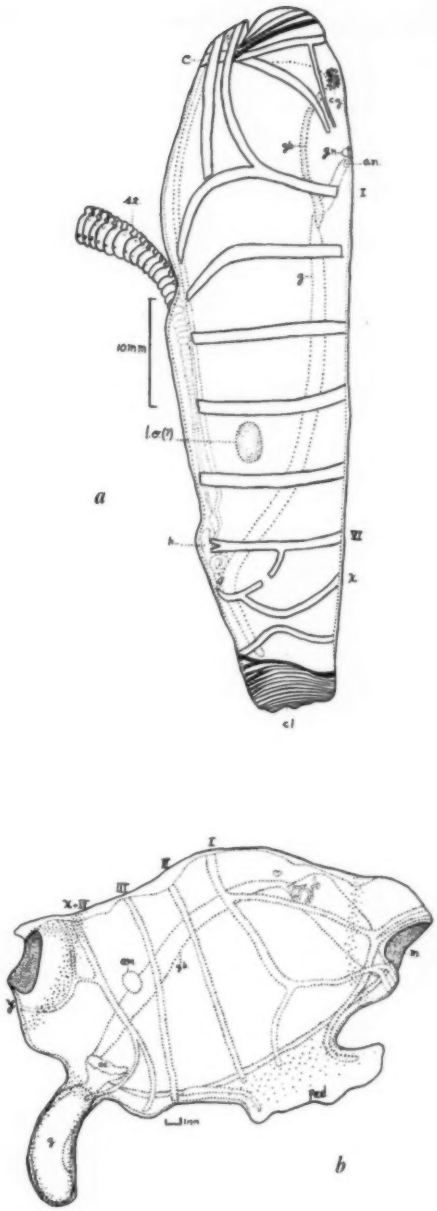

FIG. 4. *Cyclosalpa affinis*. *a*, Solitary form, left side; *b*, aggregate from, right side.

y connected by a laterodorsal branch. *Ciliated groove:* Anterior to M I, highly convoluted. *Viscera:* Gut a large open loop, forming a posteroventral evagination beyond body outline; testis contained in gut loop; embryo on right side between M III and IV; no light organs.

Cyclosalpa floridana (Apstein) 1894
Fig. 5*a*, *b*

Cyclosalpa dolicosoma-virgula Traustedt, 1893: 5.
[non] *Salpa virgula* Vogt, 1854: 11.
Salpa floridana Apstein, 1894*b:* 9.
Cyclosalpa floridana Brooks, 1908: 75 [*fide* Sewell, 1926]; Ihle, 1935: 527–529; Ihle and Ihle-Landenberg, 1935: 21; Thompson, 1948: 111.

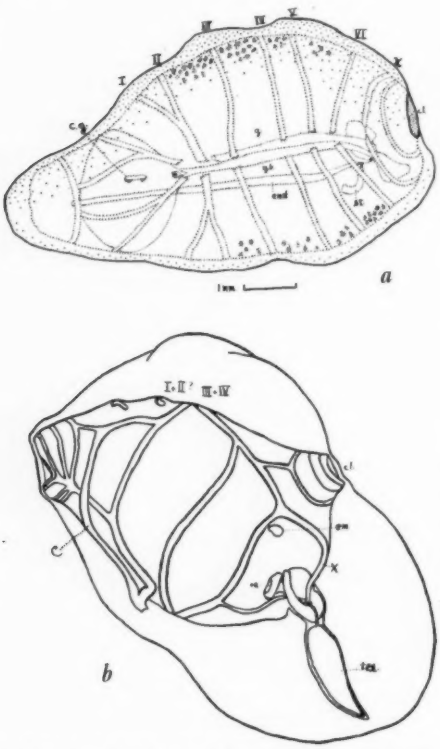

FIG. 5. *Cyclosalpa floridana. a*, Solitary form, dorsal surface; *b*, aggregate form, left side (modified after Metcalf, 1918).

Salpa (*Cyclosalpa*) *floridana* Metcalf, 1918: 32; Sewell, 1926: 72.
[non] *Cyclosalpa floridana* Apstein 1906*a:* 248; 1906*b:* 162.

SOLITARY FORM: One specimen examined with length of 8 mm. (Fig. 5*a*). *Test:* Rather thick, glutinous; with no definite elevations or depressions; rather far separated from mantle; attached at mouth and cloacal opening. *Muscles:* All six interrupted dorsally, ventrally continuous and fused into a single mass; M I–II joining dorsally; M I joining mouth muscles. *Ciliated groove:* Simple crescent with points turned ventrally. *Viscera:* Esophagus joins intestine ventrally at level of M VI; single, ventral caecum projecting from point where intestine courses antero-obliquely with gill; anus opening at level of M II (Metcalf shows this anterior to M I just under ganglion); light organs patchy masses of cells between the following muscles on each side: II–III–IV–V–VI.

AGGREGATE FORM: Two specimens examined, with lengths of 2.5 and 4 mm.

As both POFI specimens are in very poor condition, the following description is based on Metcalf, as is the figure (Fig. 5*b*). *Test:* Thin, far separated from body except at mouth and cloacal openings; forming a large bulge or swelling posteroventrally for testis and gut. *Muscles:* Three body muscles; M I joining mouth muscles and, with M C, forming peduncle muscles; M I–II and III–IV–x converging dorsally; M III–IV–x joining dorsally, converging ventrally; all muscles continuous dorsally and ventrally; x joining y by a bridle piece which extends over gut. *Ciliated groove:* Simple crescent. *Viscera:* Intestine forming a close loop, anus opening on left behind esophageal opening; testis large, projecting posteroventrally from gut; embryo located between M IV and x laterally.

Cyclosalpa bakeri Ritter (1905)
Fig. 6*a–c*

Cyclosalpa bakeri Ritter, 1905: 54; Ihle, 1935:

527–529; Thompson, 1948: 114; Tokioka, 1951: 183.

Cyclosalpa floridana Apstein, 1906*a:* 248; 1906*b:* 162.

[non] *Salpa floridana* Apstein, 1894*b:* 9.

Salpa (*Cyclosalpa*) *bakeri* Metcalf, 1918: 37.

SOLITARY FORM: One specimen examined with length of 34 mm. (Fig. 6*a*, *b*). *Test:* Thin, flabby, glutinous; closely attached to mantle; no definite elevations or depressions; pear-shaped with posterior end smallest. (This does not agree with the figure of Metcalf, which shows the test far separated from the mantle.) *Muscles:* Six body muscles, of which M I joins mouth muscles laterally and ventrally; all body muscles and x dorsally interrupted (Ritter, 1905, and Metcalf, 1918, say that x is sometimes complete dorsally), all except x ventrally interrupted (the above-named authors say that x is also ventrally interrupted); ventrally, y fusing with its fellow of the opposite side, extending shortly anteriorly between the gut caeca; dorsally M VI extending anteriorly almost to level of M II (to level of M IV according to Ritter and Metcalf); left and right anterior dorsal extensions of M VI remaining distinct. *Ciliated groove, ganglion and eye:* Ciliated groove forming an open U with left horn extended farther anteriorly; ganglion and eye just anterior to M I. *Viscera:* Esophagus opening at region of M VI ventrally; intestine accompanying gill antero-obliquely, anus opening behind eye level; two equally long, laterally compressed caeca projecting posteriorly; stolon held within a mantle tube which opens at level of M I–II; light organs large and distinct, four on one side, three on other in POFI specimen; each located laterally over a body muscle (previous reports show five large light organs and one small anterior one, between body muscles).

This animal most closely resembles the *polae* form of *Cyclosalpa pinnata* (according to the description of Sigl, 1912*a*, and the statement of Thompson, 1948). It can be distinguished from that form by the nonfusion of the two M VI dorsally, and by the fact that in *C. bakeri* the caeca are of equal length, whereas in *C. pinnata* they are unequal.

AGGREGATE FORM: Eight specimens examined with length range of 7–9 mm. (Fig. 6*c*). *Test:* No definite elevations or depressions; flabby, thin except around posterior projections; either closely applied or far separated from mantle; attached at cloacal siphon and mouth; two prominent posterior end projections of thicker test present; the whorl of zooids released from the stolon covered by an outer coat of test, including seven zooids both in my specimens and in Thompson's figure (1948, pl. 42). *Muscles:* Two main muscle groups dorsally; each dividing laterally into several branches; anterior group joining mouth muscles; peduncle muscles three on each side, anterior one from M C, lateral one from M I–II, and a short posterior one from M III which extends anteroventrally toward peduncle; muscles of posterior muscle mass continuous ventrally; muscle structure asymmetric. *Ciliated groove, ganglion and eye:* All anterior to M I; ciliated groove forming a crescent rather far anterior to ganglion and

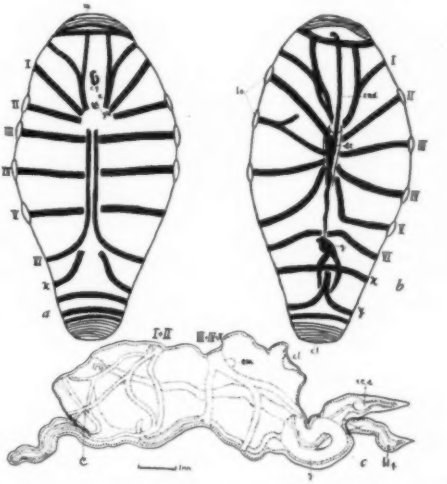

FIG. 6. *Cyclosalpa bakeri. a*, Solitary form, dorsal aspect; *b*, solitary form, ventral aspect (*a* and *b* schematic; length of animal, 34 mm.); *c*, aggregate form, left side.

eye; latter just in front of M I, prominent. *Viscera:* Gut forming posterior loop at base of posterior projections beyond body margin; anus opening at esophageal level; testis occupying left posterior projection; a caecum from the gut plus a smaller "problematic" organ, considered by Metcalf to be probably homologous with the same organ (=blood-forming organ) of *Ritteriella*, occupying the right posterior projection; embryo located at region of posterior muscle mass on right side.

Genus HELICOSALPA Todaro, 1902

I have not seen the report of Todaro (1902) establishing this genus. Ihle (1935) stated in regard to Todaro's report, "Durch die starke Enantiomorphie, durch das Fehlen einer ringförmigen Anordnung der Blastozooide in der Kette und durch die eigentümlichen Haft-Flächen weicht *Cyclosalpa virgula* (Vogt) so bedeutend von den anderen Arten ab, dass Todaro (1902) diese Art zur selbständigen Gattung *Helicoslapa* rechnete." Ihle did not follow this classification, considering the species *C. virgula* to agree so closely with the other cyclosalpas in muscle arrangement and structure of gut that he thought it should not be separated from them.

After careful examination of the species *H. virgula* and *H. komaii*, however, I am of the opinion that they are quite different from the species of *Cyclosalpa;* thus I agree with Todaro (1902). As *Helicosalpa virgula* was at that time the only known species of the genus, it must be considered the type.

The genus may now be characterized as follows.

1. There are two distinct gregarious forms produced on the stolon, the dextral and the sinistral individuals. Whorls are not produced on the stolon. Mirror imagery is shown in the arrangement of attachment organs, musculature, tentacle over the ciliated groove, the ciliated groove, testis, and posterior projection (*H. virgula*), eye, mouth, and cloacal siphon. Other variations in the two forms, although not mirror imagery, are the position of the testis and posterior projection (*H. komaii*), embryo, gut, and anus ("primary asymmetry" of Komai, 1932; the mirror imagery is called "secondary asymmetry" by him). In a few other species of Salpidae (for example, *Brooksia rostrata* and *Ihlea punctata*) asymmetry occurs, but this apparently is secondary asymmetry.

2. There is no peduncle, only a blunt attachment organ by which the gregarious forms attach to the stolon. The body muscles do not enter this process as do the peduncle muscles of *Cyclosalpa*.

3. The solitary form possesses dorsal and ventral longitudinal muscles which are continuous with M I; the dorsal longitudinal muscles are paired (*H. virgula*) or united (*H. komaii*). The ventral longitudinal muscles are always paired; they are distinct from most transverse muscles (*H. virgula*) or joined by all transverse (body) muscles (*H. komaii*).

4. The anus of the solitary form is turned widely posteriorly from the anterodorsal region of the gill bar, forming a rectum.

The nearest known relative of *Helicosalpa virgula* and *H. komaii* is probably *Cyclosalpa bakeri*. Metcalf (1918) included *H. virgula* and *C. bakeri* in his group *Cyclosalpae asymmetricales* but did not attain a phylogenetically accurate division, stating: "The division of the subgenus into *Cyclosalpae symmetricales* and *Cyclosalpae asymmetricales*, while truly descriptive of the existing conditions, does not represent accurately degrees of relationship, for *Cyclosalpa bakeri*, an asymmetrical form, finds it nearest relative in *C. floridana*, an aberrant member of the group *symmetricales*."

The separation of *H. virgula* and *H. komaii* into a separate genus is considered phylogenetically valid, distinguishing them from the cyclosalpas.

Helicosalpa virgula (Vogt) 1854
Fig. 7*a–d*

Salpa virgula Vogt, 1854: 11.

Salpa dolicosoma Todaro, 1883: 41.
Salpa dolicosoma-virgula Traustedt, 1885: 360.
Helicosalpa virgula Todaro, 1902: 405.
Cyclosalpa virgula Apstein, 1906*b*: 161; Ihle, 1935: 527–529; Ihle and Ihle-Landenberg, 1936: 274; Thompson, 1948: 118.
Salpa (*Cyclosalpa*) *virgula* Streiff, 1908: 15; Metcalf, 1918: 43; Sewell, 1926: 73; Stiasny, 1926: 418.
[non] *Cyclosalpa dolicosoma-virgula* Traustedt, 1893.
[non] *Salpa* (*Cyclosalpa*) *virgula* Komai, 1932: 70.

SOLITARY FORM: One specimen examined with length of 141 mm. (Fig. 7*a*,*b*). *Test:* The test of this specimen is relatively huge compared with the body. Volumetric measurements were made by water displacement: the body measured 10 milliliters, whereas the test measured 148 milliliters. This great difference in volume has not been reported before, thus perhaps it is only an anomaly. Test globular, gelatinous, thick and flabby; slightly glutinous; formed of an outer thin membranous layer and a thick inner gelatinous layer; loosely attached to the body by a few fine strands of test tissue; without permanent elevations or ridges. Posterior languets shown by Metcalf (1918) not present in POFI specimen, but a pair of short test projections present at the cloacal region. *Muscles:* M I and VI are continuous dorsally on each side, forming two dorsal longitudinal muscles; M I extending posteriorly on ventral surface forming two ventral longitudinal muscles that end at region of stolon extrusion; M V interrupted dorsally, extending ventrally almost to stolon level as an anteriorly directed longitudinal muscle, thus almost meeting the posteriorly extended M I; M II, III, IV, and x dorsally and ventrally interrupted; M I joining mouth muscles. The close relationship of this species and *H. komaii* is evident from the similarity of muscle structure. It can easily be distinguished from it, as *H. virgula* possesses two dorsal longitudinal muscles rather than

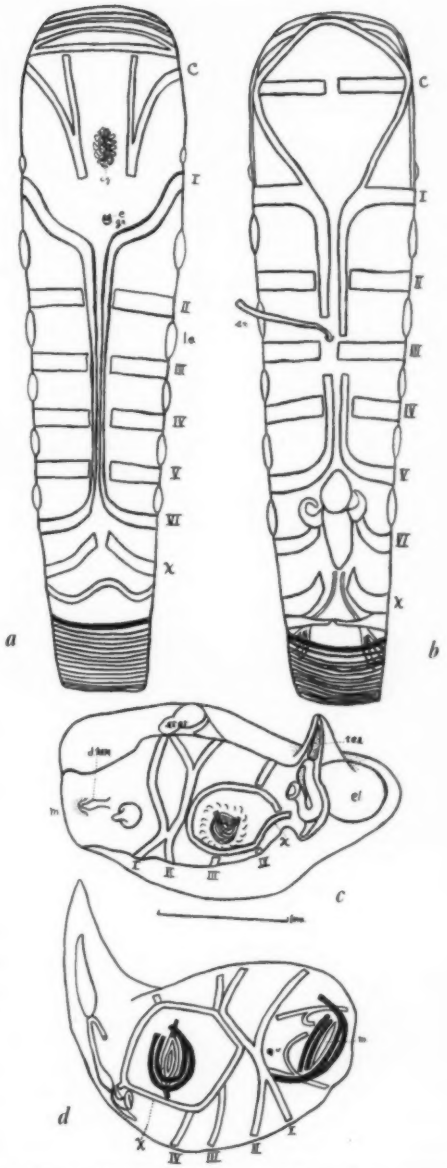

FIG. 7. *Helicosalpa virgula*. *a*, solitary form, dorsal aspect; *b*, solitary form, ventral aspect (*a* and *b* schematic, not showing the test; length, 141 mm.); *c*, aggregate form, sinistral individual from stolon, dorsal aspect; *d*, aggregate form, dextral individual, dorsal aspect (after Ihle, 1937–39, modified from Streiff, 1908).

one, and the ventral longitudinal muscles of *H. virgula* are not continuous (Streiff, 1908, however, represented them as continuous). In addition, the ventral ends of M II–IV remain distinct from longitudinal muscles in *H. virgula*. *Ciliated groove, ganglion and eye:* Ciliated groove highly convoluted, located at level of dorsoposterior extensions of M C; ganglion and eye at level of dorsal longitudinal muscles. *Viscera:* Gut large, bearing two caeca; intestine extending obliquely with gill, turning posteriorly at level of M I; stolon extruding from test at level of M III; six light organs on each side between body muscles from I to VI; additional small light organ anterior to M I (Streiff, 1908, Metcalf, 1918, and Stiasny, 1926, show a single continuous light organ extending from M I to M VI on each side; the photograph by Thompson, 1948, also shows a continuous light organ on each side; evidently, there is considerable variation in their location and structure).

AGGREGATE FORM: Only stolonic individuals were studied with length of 3 mm. (Figs. 7*c*,*d*).

The aggregate forms of this species and *Helicosalpa komaii* are the most asymmetric of all the salps. The two types of aggregate individuals that are produced, dextral and sinistral, are described separately.

Dextral individual (Fig. 7*d*): This has been figured by Streiff (1908) and Metcalf (1918). In addition, Streiff described the sinistral individual, but Metcalf apparently had only dextral individuals for study. Test thick and firm with a bulbous swelling around elaeoblast and a large pointed projection containing part of gut and testis projecting dorsolaterally toward anterior left side of body; anus directed toward right; eye turned slightly to right of mid-line of body, as is the cloacal opening; four body muscles; x prominent, encircling cloaca, separating the two parts of M IV; dorsal tentacle projecting over ciliated groove to left of and anterior to ganglion.

Sinistral individual (Fig. 7*c*): Test similar to above, except projection containing gut and testis directed to right; anus directed toward left; ganglion and eye slightly to left of mid-line of body, as is cloacal opening; muscles the mirror image of dextral individual; dorsal tentacle over ciliated groove projecting anteriorly and slightly to right of ganglion.

Helicosalpa komaii
(Ihle and Ihle-Landenberg) 1936
Fig. 8*a–f*

Salpa (*Cyclosalpa*) *virgula* Komai, 1932: 70.
[non] *Salpa virgula* Vogt, 1854: 11.
Cyclosalpa komaii Ihle and Ihle-Landenberg, 1936: 274; 1938*b*: 609; Tokioka, 1937: 221.
Cyclosalpa virgula Fedele, 1937: 448, 525 (*fide* Ihle and Ihle-Landenberg, 1938*b*).
[non] *Salpa virgula* Vogt, 1854: 11.

SOLITARY FORM: One specimen examined with length of 94 mm. (Komai's specimen was 230 mm. long, making this the largest of all known salps.) (Fig. 8*a–d*.) *Test:* Thick, flabby, strongly attached to mantle by numerous fine strands of test material; a prominent, nonserrated, middorsal ridge present on anterior half of test; without other permanent elevations or depressions; test composed of a thin outer layer and a thicker inner gelatinous layer; inner layer opaque (staining makes it more opaque, so should be used only with caution). Komai (1932) stated, "The test is thin and soft." I presume that he examined only the outer surface, which appears without dissection to be thin and rather far separated from the mantle by the inner gelatinous layer. *Muscles:* Six body muscles; x and y branched (Komai's figure, 8*c* of this report, shows y as a nonbranched muscle); mouth musculature including the large M C that approaches or touches M I dorsolaterally, passes backward ventrally as the ventral longitudinal muscle; two large sphincters of the dorsal lip (according to Komai, one large posterior and three small anterior ones) appearing to fuse laterally with two sphincters of the ventral lip, then continuing posteriorly as a dorsal retractor to the outside

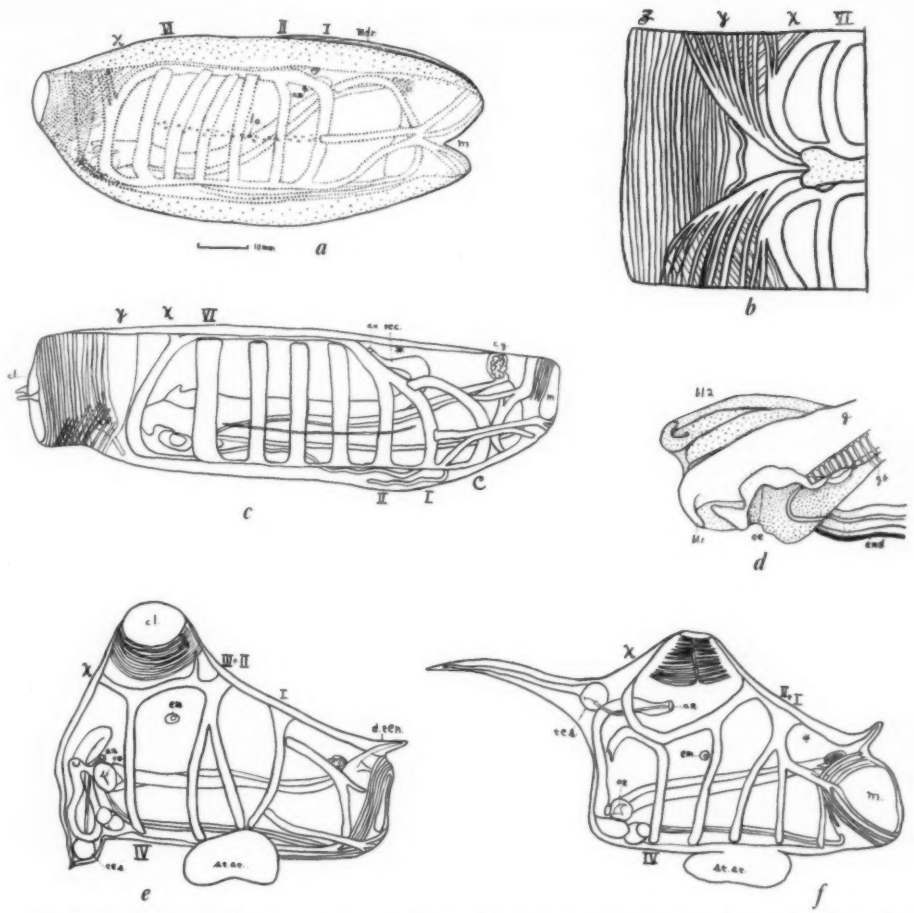

FIG. 8. *Helicosalpa komaii*. *a*, Solitary form, right side; *b*, solitary form, inside view of ventral cloacal region; *c*, solitary form (230 mm.), right side (after Komai, 1932); *d*, solitary form, posterior part of gut, right side (blind sac 2 has been turned slightly dorsad); *e*, aggregate form (about 50 mm.), sinistral individual, right side; *f*, aggregate form (about 70 mm.), dextral individual, right side. (*e* and *f* after Komai, 1932).

of M I, and as a ventral retractor which courses with M C as part of the ventral longitudinal muscle. Komai shows the dorsal retractor muscle formed only by ventral lip sphincters 1 and 2, the ventral retractor muscle formed by ventral lip sphincter 3. The specimen before me is rather mutilated anteriorly, so my description perhaps is wrong in some details. M I–II continuing dorsally as unpaired dorsal longitudinal muscle joining x; x forming ventral longitudinal muscle (paired) which receives contributions from all body muscles as well as ventral retractor and M C of mouth region; there is thus a continuous rectangular muscle band which includes parts of all the major muscles of this animal. *Ciliated groove, ganglion and eye:* Ciliated groove highly convoluted, located anteriorly at level of M C; ganglion and eye at level of M I–II, just over rectum. *Viscera:*

Intestine elongate, coursing obliquely dorsad with gill, separating from it at level of M I forming a prominent posterior bend (rectum); forming two prominent caeca posteriorly which project equally posteroventrally in the POFI specimen, whereas Komai's figure shows one caecum projecting dorsoanteriorly, the other posteroventrally; stolon passing anteriorly in sinuous course, turning posteriorly just in front of M I (from Komai; the POFI specimen has no stolon); light organ composed of sparse masses of cells from M I–VI on each side of body.

AGGREGATE FORM: As no specimens of this form have been examined, the description follows those of Komai (1932) and Tokioka (1937). Length range of known specimens (Komai) 20–55 mm. without projections.

Dextral individual (Fig. 8*f*): Body ovoid, texture soft; one long posterior projection present; a cushion-shaped attachment organ on left ventral surface; atrial opening dorsal, tubular; musculature closely similar to that of *H. virgula;* gut forming open U-shaped loop at base of posterior projection; esophagus and left ventral caecum directed anteriorly; intestine extending dorsally, rectum bending anteriorly; small right caecum protruding to the right; testis spherical, located posterior to gut at base of posterior projection; a "whitish core" extending from testis to rear of posterior projection (considered by Komai probably homologous to the blood-forming organ of *Ritteriella*); ciliated groove highly convoluted; a prominent horn-like process borne dorsoanteriorly over ciliated groove.

Sinistral individual (Fig. 8*e*): Musculature the mirror image of that of dextral individual; attachment organ on right ventral surface; horn-like projection over ciliated groove extending dorsally toward right; posterior projection short, forming a blunt cone; esophagus and anus close to one another, located dorsally; esophagus coursing posteriorly, intestine bending ventrally, then dorsally and opening on left side of esophagus; left caecum large, opening into upper part of intestine of left; right caecum small, opening below left one on right side; testis spherical, ventral to gut, in base of cone-shaped projection.

Embryo in both types located on dorsal right side between M III and IV. The horn-like projection is absent in very young individuals (as this is present in young *H. virgula* from the stolon, perhaps this is incorrect).

This species has been reported only from Seto, Japan (Komai, 1932), and the present specimen is from 7°4″N, 140°4″W. Komai (1932) described both the solitary and aggregate forms (one and *ca.* 30 specimens, respectively), considering them *S.* (*C.*) *virgula.* Ihle and Ihle-Landenberg (1936) studied *H. virgula* critically, comparing their observations with those of Komai. They concluded that his specimens were a distinct species which they named after him. Tokioka (1937) agreed with this conclusion and figured and described the gut and associated structures of gregarious specimens, apparently from the same collection on which Komai worked.

Fedele (1937) found that the dorsal tentacle above the ciliated groove of gregarious individuals is also present in *H. virgula.* He considered the spherical testis of *H. komaii* to be only a condition of age and therefore regarded Komai's specimens as identical with *H. virgula.* Ihle and Ihle-Landenberg (1938*b*) wrote a short note defending their earlier conclusion. They agreed that the dorsal tentacle is also found in *H. virgula,* but the spherical testis was not present; this conclusion is supported in the present report, as all stolonic individuals of *H. virgula* possess an elongate testis, never a spherical one. In addition, the solitary form of *H. komaii* is so different from *H. virgula* that they regarded their earlier conclusion as the correct one, with which I am in complete agreement.

SALPINAE subfam. nov.

This subfamily may be distinguished by the following characteristics: (1) In both forms the gut is completely free from the gill, except at the esophageal region, and does

not accompany the gill; (2) there are no distinct light organs present in either form (the gut of some species produces light from diffuse bodies); (3) the gut in the aggregate form is a more or less compact "nucleus," never a loosely formed loop or an extended tube; (4) attachment organs in the aggregate form are separated, not united into one process; thus, there are two or more attachment organs in each animal.

Genus BROOKSIA Metcalf, 1918

Solitary form with six body muscles, aggregate form with four and five. Solitary form with an anterior snout containing two pairs of longitudinal muscles, the dorsal pair continuous with the mouth musculature, the ventral pair formed by M I and C?. Ventral longitudinal muscles extend posteriorly to gut region. Aggregate form with testis outside intestinal coil, with short anteriorly upturned endostyle. Aggregate form asymmetric.

One species, *Brooksia rostrata*.

Brooksia rostrata (Traustedt) 1893
Fig. 9*a–e*

Salpa rostrata Traustedt, 1893: 8; Sigl, 1912*b* (*fide* Thompson, 1948).

Salpa (*Brooksia*) *rostrata* Metcalf, 1918: 50; Sewell, 1926: 84.

Brooksia rostrata Ihle, 1935: 527–529; Ihle and Ihle-Landenberg, 1935: 24; Thompson, 1948: 120.

SOLITARY FORM: More than 10 specimens examined, with length range of 2–31 mm. without snout (probable range of 4–62 mm. with snout). (Fig. 9*b–e*.) *Test:* Flabby, glutinous, without permanent elevations or depressions; usually absent or fragmentary in preserved specimens. *Muscles:* Six dorsally continuous body muscles present; M I–III and IV–V–VI–x forming groups dorsally; M III–IV touching laterally; a strong longitudinal muscle coursing on each side of endostyle from gut to anterior tip of snout (they remain separate throughout their length); these longitudinal muscles joined by M C? and M I only (this is contrary to Traustedt, 1893, and Thompson, 1948, but on close examination, one can see that no other muscle fuses with them as Ihle, 1910, showed). In addition to extensions of the ventral longitudinal muscles, the snout contains two dorsal longitudinal muscles that continue with the oral retractor. I have thus classified them as M b_3, or ventral lip sphincter 3. The oral retractor is formed by the first dorsal lip sphincter (A_1) and all three ventral lip sphincters. M B_1 and C extend to just behind the oral retractor. An independent muscle, probably formed from M C or B_1 (I have labeled it C?), extends ventrally to join the ventral longitudinal muscle, as does M I. In one specimen, M I is dorsally interrupted, probably unnaturally. The horizontal muscle (*c*) is long and relatively narrow. The cloacal musculature of Figure 9*c*, *d* has been reconstructed from fragments. *Ciliated groove, ganglion and eye:* Ciliated groove long, sinuous in large specimens, short and simple in smaller ones. The eye has the usual horseshoe shape. Ganglion and eye lateral to ciliated groove in large specimens, dorsal to it in smaller ones. *Viscera:* Gut somewhat compressed laterally; margined by a thin flap of caecum (?) tissue; in state E (Ihle and Ihle-Landenberg, 1935). The stolon is directed posteriorly.

AGGREGATE FORM: More than 10 specimens examined with length range of 0.8–2.5 mm. (Fig. 9*a*). *Test:* Flabby, glutinous, usually absent in preserved animals. *Muscles:* Body muscles fused dorsally and ventrally into a single mass; asymmetric, with two types produced, the sinistral and dextral individual, whose muscles are mirror images. There are apparently four body muscles on one side and five on the other, but due to the invariably poor condition of preserved specimens, musculature is difficult to study; consequently, this needs further examination. *Ciliated groove:* Simple, anterior to M I. *Viscera:* Anterior end of endostyle widely turned dorsally; endostyle short; gut in state A (Ihle, 1937–39);

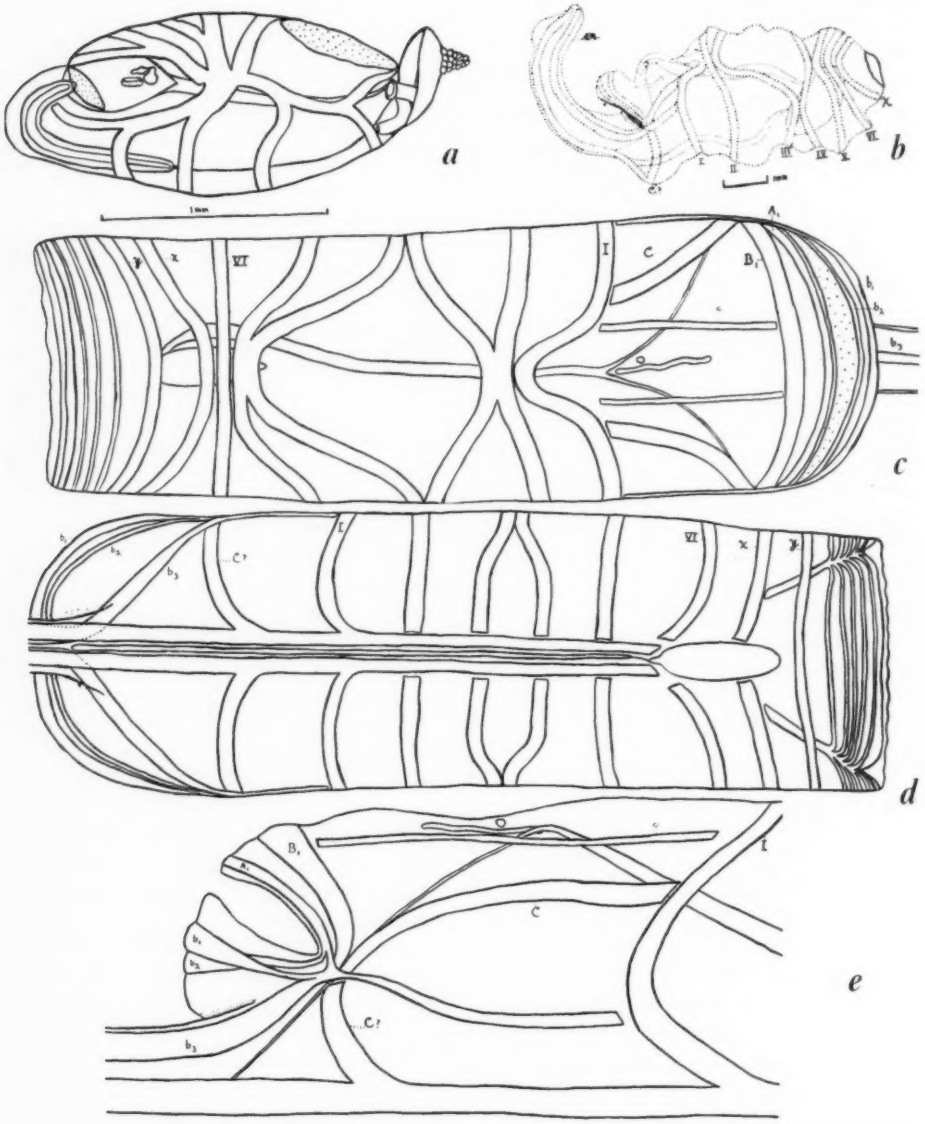

FIG. 9. *Brooksia rostrata*. *a*, Aggregate form, left dorsal aspect; *b*, solitary form, specimen without test, left dorsal aspect; *c*, solitary form, diagram of dorsal surface (length without snout, 31 mm.); *d*, same specimen as *c*, ventral surface; *e*, same specimen as *c*, mouth region, left lateral aspect.

testis located posterior to gut, unlike all other Salpinae.

This form, because of its small size, is easily confused with *Thalia democratica* agg. The presence of the widely turned endostyle, prominent gut with posterior testis, and dorsal and ventral muscle masses make it readily distinguishable.

Previously this species has been considered rare, although, as Apstein (1894) and Thompson (1948) stated, the very small aggregate form may easily be overlooked, especially among large numbers of *Thalia democratica* agg. The species is common in the POFI collections; in one plankton sample, for example, there were 8 solitary and 38 aggregate zooids. These animals are delicate and usually fragmented. Only two specimens of the solitary form retained the snout. The solitary zooid can be positively identified by the longitudinal muscles coursing parallel to the endostyle; the aggregate zooids must be examined closely, preferably stained, for correct identification. Fragments should not be overlooked but stained and examined, as the snout is useful as a recognition character only if the animal is whole. The high muscular activity of the solitary zooid was shown by the fact that in many specimens the body was turned completely inside out.

Genus IHLEA Metcalf, 1919

Solitary form with six or seven body muscles which form complete rings. Aggregate form with five or six body muscles which form complete rings or are ventrally interrupted; these muscles are arranged asymmetrically.

Two species, *Ihlea punctata* (type) and *I. magalhanica*. The latter species has not been found in the POFI collections.

Ihlea punctata (Forskål) 1775
Fig. 10*a–c*

Salpa punctata Forskål, 1775: 114; Ihle, 1912: 34.
Biphora punctata Bruguière, 1789: 181.
Salpa musculosa [?] Herdman, 1888: 64.
Salpa musculosa-punctata Traustedt, 1893: 6.
Salpa asymmetrica Fowler, 1896: 994; Ihle, 1912: 35.
Salpa (*Salpa*) *punctata* Streiff, 1908: 25.
Salpa (*Apsteinia*) *punctata* Metcalf, 1918: 72 (see also Metcalf, 1919).
Salpa (*Apsteinia*) *asymmetrica* Metcalf, 1918: 78, 183 (see also Metcalf, 1919).
Ihlea punctata Ihle, 1935: 527–529.
Ihlea asymmetrica Ihle, 1935: 527–529; Tokioka, 1937: 222; Berrill, 1950: 300.

SOLITARY FORM: Eight specimens examined, with length range of 3 (embryo)–14 mm. (Fig. 10*a*). *Test:* No specimen of the solitary and aggregate generations except the embryo had the test attached. It is probably loosely attached to the adult. The test of the embryo is flabby, rather thick around gut and elaeoblast area; without distinct elevations or de-

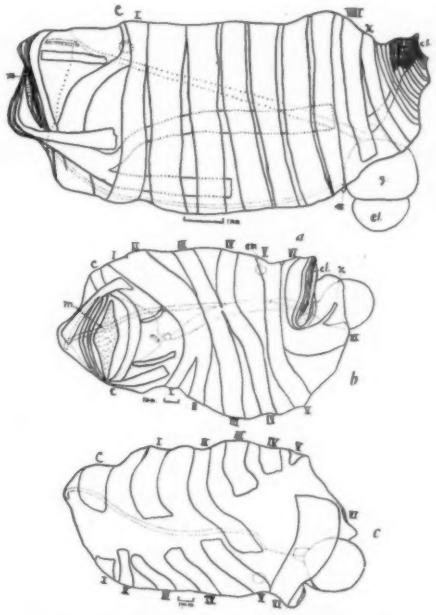

FIG. 10. *Ihlea punctata*. *a*, Solitary form, left side, slightly dorsal; *b*, aggregate form, dorsal aspect; *c*, aggregate form, ventral aspect.

pressions; with one lateral attachment organ on each side over cloacal muscle x. *Muscles:* Ten large muscles of which the first is M C; M I fused with C dorsally; M VI–VII fused ventrally; remaining body muscles distinct dorsally and ventrally; M C, I–VII, and x forming complete rings; M VIII interrupted ventrally, continuous dorsally; ventral oral retractor extending posteriorly on each side, branching into two longitudinal bands, a dorsal one extending to posterior edge of M VII and a ventral one extending to space between M III and IV (touching IV in embryo); longitudinal muscles coursing internally to body muscles; cloacal retractor extending anteriorly beneath x to M VIII. *Ciliated groove, ganglion and eye:* Ciliated groove simple, anterior to M C. Ganglion and eye just beneath M C. *Viscera:* Gut compact, in condition D (Ihle and Ihle-Landenberg, 1933); stolon, according to earlier investigators, forming a tight spiral limited to ventral region of gut (no stolon present in POFI specimens).

AGGREGATE FORM: More than 10 specimens examined with length range of 18–23 mm. (Fig. 10*b,c*). *Test:* Not observed but body flabby, thus test probably without permanent elevations or depressions. *Muscles:* Asymmetric; six body muscles present; M I–II join dorsally as do III–IV and V–VI; all muscles interrupted ventrally; M C broad; M VI on one side extending in broad band around ventral surface of gut; M II on side opposite latter portion of VI extending posteriorly on ventral surface toward opposite side to between M V and VI. *Ciliated groove, ganglion and eye:* All anterior to M I; ciliated groove straight, simple; ganglion and eye posterodorsal to it; eye projecting dorsally toward a small opening in mantle above it. *Viscera:* Gut compact, in condition F (Ihle and Ihle-Landenberg, 1933); embryo located on right side just under M V.

On examination of the literature of *Ihlea punctata* and *I. asymmetrica*, a large number of contradictions, seemingly incorrect observations, and similarities in the descriptions of the two so-called species are noticeable.

Therefore, if some of the earlier works which seem to be permeated with faulty observations are disregarded, the reported differences between the species and my criticisms of them may be summarized as follows:

1. In *Ihlea asymmetrica* aggregate there are no pigment cells ventrally on the test, whereas in *I. punctata* these are present. The presence or absence of pigment is probably largely determined by length of exposure to the preservation fluid.

2. In *I. asymmetrica* agg. all body muscles are interrupted ventrally (Ihle, 1912; Tokioka, 1937) or only M VI is a ring (Metcalf, 1918), whereas in *I. punctata* all muscles are interrupted ventrally (Streiff, 1908; Ihle, 1912; Metcalf, 1918). Metcalf (1918) performed his study on stolonic individuals of *I. asymmetrica* which perhaps had not completed their growth and thus possessed a ring muscle; or he made an error in his observation.

3. In *I. asymmetrica* agg., M I–II and V–VI join dorsally to form groups, M III and IV remain separate (Metcalf, 1918), or M I–II, III–IV, and V–VI form groups, the second group (III–IV) joining the first (Ihle, 1912; Tokioka, 1937). On the other hand, *I. punctata* forms two groups—M I–II and V–VI—and M III–IV remain separate (Streiff, 1908; Metcalf, 1918), or M I–II and V–VI form groups, M II–III remain separate but approach M II (Traustedt, 1893; Apstein, 1906*a*). These differences in muscle grouping seem to be only individual variation. They overlap in part and are considered nonuseful here.

4. In *Ihlea asymmetrica* sol., the dorsal longitudinal muscle extends to M VIII; the ventral longitudinal muscle extends to beneath M V (Ihle, 1912; Metcalf, 1918). In *I. punctata*, on the other hand, the dorsal longitudinal muscle extends to between M VII and VIII (Apstein, 1906*a;* Streiff, 1908; Ihle, 1912; Metcalf, 1918); the ventral longitudinal muscle extends to between M III–IV (Apstein, 1906*a;* Streiff, 1908; Ihle, 1912; Metcalf, 1918). There is obviously no difference

in the dorsal longitudinal muscle extension. The difference described in the ventral extension is perhaps only one of growth. At any rate, it is rather minor.

5. In *Ihlea asymmetrica* sol. there are lateral projections on either side of the gut in embryos (and the small specimen of Ihle, 1912), whereas these have not been reported in *I. punctata* (Apstein, 1901, Ihle, 1912, and Metcalf, 1918, have reported them in *I. asymmetrica*). As Metcalf (1918) pointed out on his embryo, lateral projections are probably only embryonic attachment organs. Thus they may disappear in adults. They are presumably present in embryos of both so-called species.

6. In *I. punctata* sol. there are pigmented areas on the lips and posteroventral region near the gut (Metcalf, 1918), whereas these have not been reported in *I. asymmetrica*. Again, the presence or absence of pigment is probably largely determined by the length of exposure to preservation fluid.

7. In *I. asymmetrica* sol., the bow muscle (C) and I, II, III, and IV form one group dorsally, M VII, VIII, and x form another (Metcalf, 1918); or C–I–II form one group, III–IV form another, and M VIII and x form a third group (Apstein, 1901); or C–I–II form one group dorsally, M III–IV a second, and M VII–VIII–x form a third group (Ihle, 1912). On the other hand, in *I. punctata* C–I–II form the only group (Traustedt, 1893); or all remain separate (Apstein, 1906*a*,*b*; Streiff, 1908); or C–I–II form one group, and VII (?)–VIII–x (figures of Metcalf, 1918) form another. These differences in muscle grouping are probably only individual variation and are considered nonuseful here.

As a result of an exhaustive review of the literature, I can conclude only three possibilities: (1) the two species may be distinct, but, if so, the descriptions are in such a tangle that they are in large part unreliable; (2) the two so-called species are one, the differences described being due only to individual variation, not to specific, subspecific, varietal, or formal variation; (3) the two species are one, the differences described being due to variations important enough, perhaps, to consider *I. asymmetrica* to be only a form or variety of the main species, *I. punctata*. This form would be distinguished from the main species only by the length of the ventral longitudinal muscle and the absence of pigmented areas in the test.

It is my opinion that possibility 2, above, is the correct one. Therefore, the two species are here regarded as only one, *Ihlea punctata* (= *I. asymmetrica*), with no differences other than what can be attributed to individual variation.

This conclusion is upheld by an embryo (solitary form) in the POFI collections. This embryo's ventral longitudinal muscle extends up to the anterior edge of M IV (a character of *I. punctata*, presumably); it also, however, possesses attachment organs—one on each side over M x (a character of *I. asymmetrica*, presumably).

Genus SALPA Forskål, 1775

Solitary form with eight ventrally interrupted body muscles, aggregate form with six. In the aggregate form, these muscles form two groups dorsally. Transverse ridges of gill bar taper gradually to a point ventrally and are separated from one another by a distance less than 0.5 the width of the gill bar.

Two species, *Salpa maxima* (type) and *S. fusiformis*.

Salpa fusiformis Cuvier, 1804

Figs. 11*a–b*, 12*a–e*, 15*b*, 16*b*

Salpa fusiformis Cuvier, 1804: 382; Bomford, 1913: 243; Ihle, 1935: 527–529; Tokioka, 1937: 223; Thompson, 1948: 156; Berrill, 1950: 293.
Salpa aspera Chamisso, 1819: 14.
Salpa runcinata Chamisso, 1819: 16.
Biphora depressa Sars, 1829: 51.
Biphora tricuspidata Sars, 1829: 56.
Salpa clostra Deshayes, 1836–46: vol. 121, figs. 2–2a.

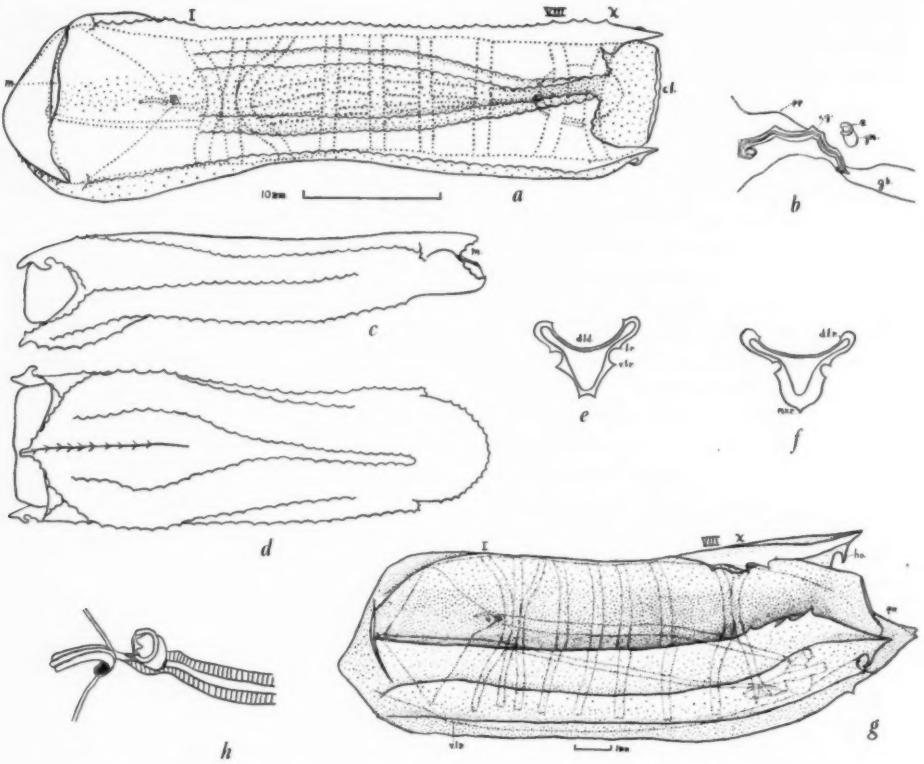

FIG. 11. *Salpa fusiformis*, solitary form. *a*, Asperate form, dorsal aspect; *b*, same specimen as *a*, ciliated groove and associated structures, dorsal aspect; *c*, same specimen as *a*, test, right side; *d*, same specimen as *a*, test, ventral surface; *e*, nonspiny form, scheme of cross section of test at level of M III; *f*, nonspiny form, scheme of cross section of test at gut level; *g*, nonspiny form, left dorsolateral aspect; *h*, same specimen as *g*, ciliated groove and associated structures, dorsal aspect.

Salpa runcinata-fusiformis Traustedt, 1885: 370.
Salpa echinata Herdman, 1888: 66.
Salpa runcinata-fusiformis var. *echinata* Apstein, 1894*a:* 47.
Salpa fusiformis var. *echinata* Apstein, 1894*b:* 14.
Salpa fusiformis-runcinata Ritter, 1905: 64.
Salpa fusiformis-runcinata form *echinata* Ritter, 1905: 67.
Salpa (*Salpa*) *fusiformis* Streiff, 1908: 24; Metcalf, 1918: 88; Sewell, 1926: 75; Stiasny, 1926: 424.
Salpa fusiformis forma *aspera* Ihle, 1911: 587; Tokioka, 1937: 223; Thompson, 1948: 158.
Salpa fusiformis fusiformis Ihle, 1912: 39.
Salpa fusiformis aspera Ihle, 1912: 40.
Salpa (*Salpa*) *fusiformis* form *aspera* Metcalf, 1918: 92; Sewell, 1926: 76.

SOLITARY FORM: More than 10 specimens examined with length range of 11–47 mm. (Fig. 11). *Test:* The typical form is described first (Fig. 11*g*): dorsal longitudinal depression wide and deep, limited on each side by a dorsal limiting ridge; each dorsal limiting ridge bearing posteriorly several spines, continuing into a dorsal posterior projection; test of dorsal longitudinal depression thin,

continuous with thin test of cloacal siphon; dorsal posterior projections bearing a blunt, straight, posterior spine and a curved ventral hook; each projection also forming a ventrally directed posterior ridge that joins the same ridge of opposite side midventrally; at joint, ventral posterior projection formed; each dorsal posterior projection bearing laterally an anteriorly directed lateral ridge; ventral to this, formed at the posterior ridge, a ventrolateral ridge courses anteriorly; ventrally a midventral ridge continuing anteriorly, dividing into two that continue to the chin; chin and mouth covered by thin test; internally test with rather large gut cavity, no elaeoblast cavity; cavity for posterior ventral attachment organ not present in typical specimens (may be present in large asperate specimens); margin of gut cavity smooth. The asperate form of this species is similar to the typical form, except that its ridges are spiny and the test has more thin area, being thick only posteriorly, at the chin and upper lip, and along ridges (Fig. 11*a*). *Muscles:* Eight body muscles; M I–III and VIII–x usually fuse, touch, or converge but may be separated; no attachment organ between M VI–VII. *Ciliated groove:* Usually forming shallow open bend (Fig. 11*b*) but may form a large structure resembling that of *Salpa maxima* (Fig. 11*b*). *Viscera:* Gut compact, in condition E (Ihle and Ihle-Landenberg, 1933); endostyle straight; stolon usually coursing anteriorly, turning abruptly and coursing around left side of gut, but may form a tight circle around gut.

AGGREGATE FORM: More than 10 specimens examined with length range of 5–37 mm. (Fig. 12). *Test:* In typical form (Fig. 12*a*), keg-shaped, smooth; with one anterior and one posterior end projection; each may be as long as body; dorsal longitudinal depression extending onto end projections, limited laterally by dorsal limiting elevations; ventrally test gradually raised, forming a relatively small gut swelling. There is an asperate form (Fig.

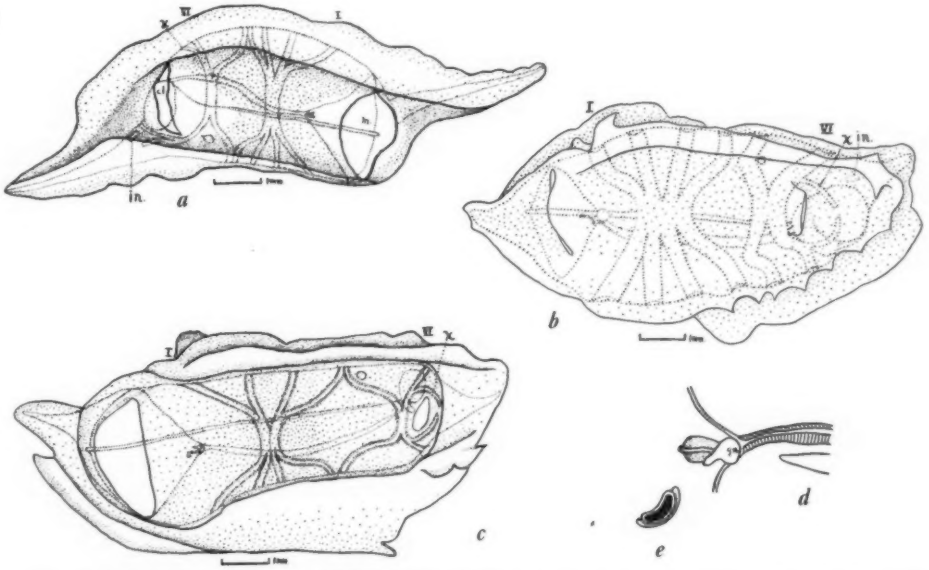

FIG. 12. *Salpa fusiformis.* aggregate form. *a*, Nonspiny form, dorsal aspect; *b*, asperate form, dorsal aspect; *c*, another asperate specimen, dorsal aspect; *d*, same specimen as *b*, dorsal aspect of ciliated groove and associated structures; *e*, ventral aspect of ciliated groove, from *d*.

12*b,c*) whose test is sparsely spined, asymmetric; end projections short, although Metcalf (1918) found some with long projections; test relatively thick. This form has broad muscle bands. *Muscles:* Six body muscles; M I–II and III–IV fusing dorsally as do M V–VI, thus forming two groups; M IV and V usually approach, touching or joining laterally, but as Stiasny (1926) pointed out, this is not so in many specimens; ends of muscles extending rather far ventrally. Ventral lip sphincter 4 (M b_3) interrupted. *Ciliated groove* (Fig. 12*d, e*): Simple, straight or slightly curved. *Viscera:* Gut compact, in condition C (Ihle and Ihle-Landenberg, 1933); gill segments closely approximated; embryo attached to right side dorsally behind or beneath M V.

Salpa maxima Forskål, 1775
Figs. 13*a–l*, 14*a–e*, 15*a*, 16*a*

Salpa maxima Forskål, 1775: 112; Ihle, 1935: 527–529; Tokioka, 1937: 223; Thompson, 1948: 154.
Salpa africana Forskål, 1775: 116.
Biphora maxima Brugiuère, 1789: 179.
Biphora africana Brugiuère, 1789: 182.
Salpa birostratus Blainville, 1827: 119.
Salpa chamissonis Lesson, 1830: 274.
Salpa forskalii [?] Lesson, 1830: 276.
Salpa birostrata Meyen, 1832: 412.
Salpa antarctica Meyen, 1832: 416.
Salpa naepolitana [?] Chiaje, 1841: 40.
Salpa africana-maxima Traustedt, 1885: 374.
Salpa (*Salpa*) *maxima* Streiff, 1908: 21; Metcalf, 1918: 83; Sewell, 1926: 83; Stiasny, 1926: 419.

SOLITARY FORM: Ten specimens examined with length range of 6 (embryo)–108 mm. (Fig. 13). *Test:* In typical specimen (Fig. 13*e*) thick in all areas, especially around gut; dorsal depression rather deep; two large dorsal limiting elevations; ventrolateral depression deep, gradually forming ventral elevation; spinose posteriorly; internally, test with large gut cavity whose posterior margin may bear elevations (called "baumförmigen Fortsätzen" of the cloacal tube, and therefore presumably of epithelium, by Streiff, 1908, and Ihle, 1912, and figured as such by them as well as later investigators); these internal test elevations may be absent or present, usually bearing several blunt spines which themselves may bear minute spines; a cavity projects ventroanteriorly from the gut cavity, housing the elaeoblast and reduced in older individuals that have resorbed the elaeoblast; anterior to gut cavity, a placental cavity present in smaller specimens; posterior to gut cavity a deep invagination for posteroventral attachment organ usually present; in one specimen (Fig. 13*e*), whole ventral region forming a cavity continuous with an opening in chin which appears to be natural, as its margin is not jagged, but not present in smaller specimens; chin prominent. In addition to the typical form, there is an echinate form that resembles the echinate form of *Salpa fusiformis* (Fig. 13*a*). It can be distinguished from the typical form only on the basis of the test. It should, perhaps, be described as typical, as this is the only form of the smaller specimens of *S. maxima* found here. Test has distinct thick and thin regions; thin dorsally and laterally except in posterior quarter of body; spines usually limited to posterior quarter of body (but not necessarily; see Fig. 13*l*); a deep longitudinal depression limited by dorsal limiting elevations (these may be ridges); transverse depression at base of upper lip; dorsal limiting elevations becoming thickened posteriorly, bearing a row of spines; just below this, a narrow longitudinal extension of thin test joins cloacal test; ventral to this a thickened region continuous posteriorly and ventrally from one side to opposite side; two weak ridges of spines on lateral surface of this thickened region; a group of spines on ventrolateral and ventral gut region; entire posteroventral region forming a gut swelling; ventral surface thickened along its entire length forming a large nonridged (but may be echinate) ventral elevation; chin rather prominent. The test as well as other structures

of *Salpa fusiformis* and *S. maxima* are in some specimens almost identical. Figure 13*l* shows a specimen of *S. maxima* of this type. *Muscles:* Eight body muscles, usually far separated from one another, but groups may be formed; extending only a short distance ventrally; attachment organ on each side dorsally between M VI and VII that may be prominent, reduced, or absent (Fig. 13*b*,*f*). *Ciliated groove* (Fig. 13*g*,*h*): Forms a large incomplete loop with three bends; in larger specimens, minor bends give the appearance of segmentation. *Viscera:* Gut compact, in condition F (Ihle and Ihle-Landenberg, 1933); stolon extending

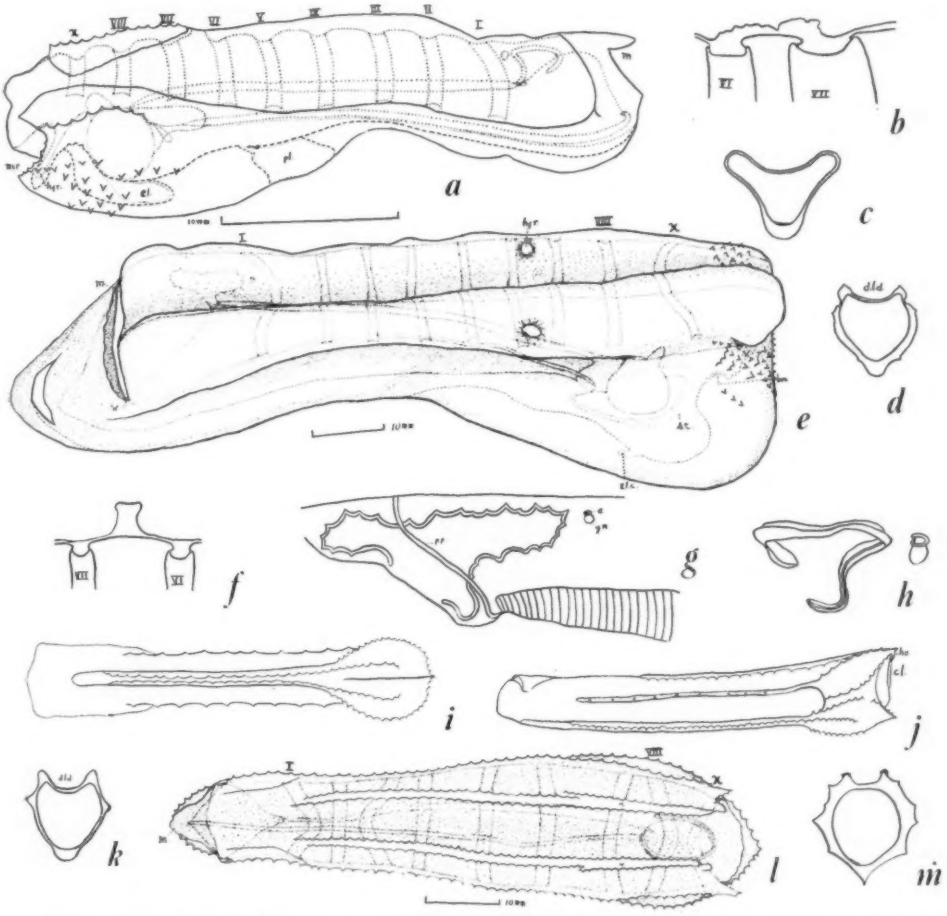

FIG. 13. *Salpa maxima*, solitary form. *a*, Smaller specimen, right side (the gut has been drawn up to reveal test cavities); *b*, dorsal attachment organ of a specimen similar to *a*, lateral aspect; *c*, same specimen as *a*, schematic cross section of test at level of M III; *d*, same specimen as *a*, schematic cross section of test at gut level; *e*, larger specimen, left side; *f*, same specimen as *e*, lateral aspect of dorsal attachment organ; *g*, same specimen as *e*, lateral aspect of ciliated groove and associated structures; *h*, same specimen as *a*, ciliated groove, ganglion and eye, dorsolateral aspect; *i*, echinate form, ventral aspect of test; *j*, same specimen as *i*, test from left; *k*, same specimen as *l*, schematic cross section of test at level of M III; *l*, another echinate specimen, dorsal aspect; *m*, same specimen as *l*, schematic cross section of test at gut level.

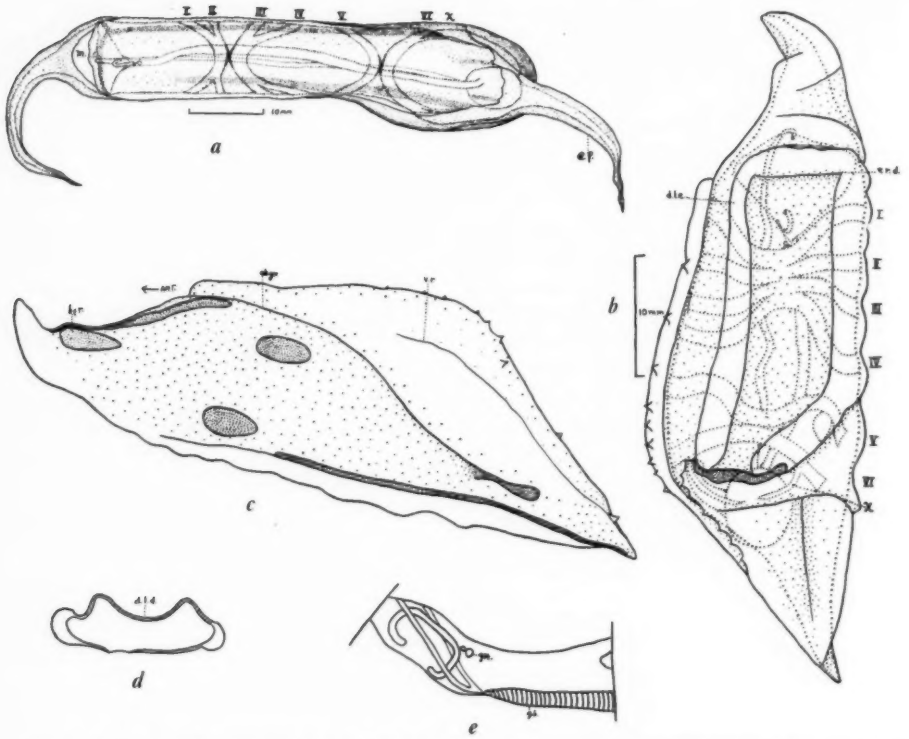

FIG. 14. *Salpa maxima*, aggregate form. *a*, Larger specimen, dorsal aspect; *b*, smaller (echinate) specimen, dorsal aspect; *c*, same specimen as *b*, ventral aspect of test; *d*, same specimen as *b*, schematic cross section of test at level of M IV; *e*, same specimen as *b*, left aspect of ciliated groove and associated structures.

anteriorly, turning posteriorly and usually rather closely encircling gut, then extending anteriorly again; a ventral posterior attachment organ usually present behind gut (Fig. 13*a*,*hft*).

AGGREGATE FORM: Over 10 specimens examined with length range of 10–112 mm. (Fig. 14). *Test:* In the typical (?) form, thick and smooth (Fig. 14*a*) in all areas; gut swelling prominent; end projections long or short; test bearing neither serrations, grooves, nor ridges; weak dorsal longitudinal depression and large ventral elevation present; gut cavity large, its margin smooth except for a V-shaped depression posteriorly. The most common form among POFI specimens is asymmetric, echinate, and smaller than the above-described form (Fig. 14*b*). Test thick in all areas; dorsal longitudinal depression limited by dorsal limiting elevations; transverse depression at base of upper lip; posteriorly a sparsely serrated dorsolateral ridge with a sparsely serrated lateral ridge ventral to it; a dorsal transverse groove posterior to cloacal aperture with a longitudinal groove extending from it posteriorly on the end projection; few spines on or near gut swelling; nonserrated ventral ridge on gut swelling; oblique groove in front of gut swelling; remaining anterior test thin, forming a shallow depression; attachment organs prominent, large; end projections broad, relatively short. *Muscles:* Six present, forming two groups, M I–IV and V–VI; IV and V may approach laterally and

even touch; muscles extending far toward ventral surface. Ventral lip sphincter 4 (M b_3) continuous. *Ciliated groove* (Fig. 14*e*): Anterior to M I, usually forming a large incomplete circle. *Viscera:* Gut compact, in condition C (Ihle and Ihle-Landenberg, 1933); embryo on right side dorsally between M V and VI.

The form *tuberculata* of Metcalf has not been found in the collections studied.

Individuals of the species of *Salpa* (solitary form) smaller than 2 centimeters have characteristic features. The two species can be distinguished by the presence in *S. maxima* of a large elaeoblast and cavity, a large ciliated groove with three bends, the usually separated muscles, and the absence of a ventral hook on the dorsal posterior test projection, whereas *S. fusiformis* has opposite characteristics (except for the presence of an elaeoblast in very young animals). When the animals are larger, these distinctions become gradually less apparent; the elaeoblast becomes reduced or resorbed, although in all specimens of *S. maxima* its test cavity remains; the ciliated groove of large *S. fusiformis* (47 mm. maximum length of POFI specimens) may have the same structure as that of *S. maxima;* the body muscles may either be grouped or distinct in both species; the internal "baumförmigen Fortsätzen" may be absent in *S. maxima;* large individuals of *S. maxima* may develop a ventral hook on the dorsal posterior test projection exactly as in *S. fusiformis* (Fig. 13*j*). Attachment organs, test, ganglion and eye, stolon, gut, and endostyle are either the same in both species or intergrade between them. The only structure that I have found never to intergrade is the cavity in which the elaeoblast lies in *S. maxima*. In all specimens examined, the elaeoblast cavity, although reduced in larger individuals, was present when the animal was considered, by other means, to be *S. maxima*. In all specimens considered to be *S. fusiformis*, even those as small as 11 millimeters, neither the elaeoblast nor its cavity was present. In small *S. fusiformis* the ciliated groove is a simple open one; in *S. maxima*, even in advanced embryos, the ciliated groove is large and possesses the characteristic three bends. Thus, the most important differences between the two species are (1) the presence in *S. maxima* of an elaeoblast cavity (both large and small individuals), and (2) the structure of the ciliated groove.

As a result of insufficient descriptions, it is impossible to determine from the literature whether the asperate forms described and fig-

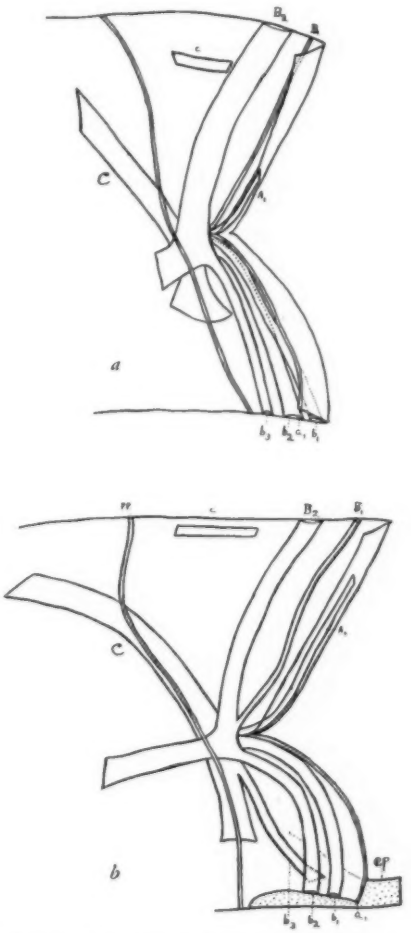

FIG. 15. Mouth musculature of left side, seen from inside. *a*, *Salpa maxima* agg.; *b*, *Salpa fusiformis* agg.

ured are *S. fusiformis* or *S. maxima* (see especially Herdman, 1888; Apstein, 1894*b*; Ritter, 1905; Ihle, 1910), although these were all considered *S. fusiformis*. I am inclined to regard the very large specimens described by some of these authors as *S. maxima*, but this is only speculation.

There is less difficulty in distinguishing the two species in the aggregate generation than in the solitary generation. Body muscle arrangement is a poor means of distinction (Stiasny, 1926). Nevertheless, it has been the main basis for differentiating *S. fusiformis* from other species. In the POFI collections, some individuals of *S. maxima* were found in which M IV and V touch laterally (usually considered a character of *S. fusiformis*), and many specimens of *S. fusiformis* were found in which, on either one or both sides, M IV and V do not touch. Other body structures, such as test, gut, position of embryo, and ciliated groove, are similar or intergrade between them. The differences in mouth musculature are the only certain means of distinguishing the two species in all specimens examined. In *S. maxima*, ventral lip sphincter 4 (M b_3) is continuous, whereas in *S. fusiformis* it is interrupted; there are also other differences as shown in Figure 15.

The great difference in size is usually a useful means of distinction between the species for both solitary and aggregate specimens.

Genus WEELIA gen. nov.

The genus is characterized as follows: In both generations, transverse ribs of the gill bar meet dorsally, becoming reduced in width sharply toward the ventral surface so that they are far separated from one another ventrally (Fig. 16); gut in state E of Ihle and Ihle-Landenberg (1933) in both generations; aggregate form with five body muscles that form two groups dorsally (M I–III, IV–V); body muscles interrupted ventrally in both forms; no independent muscle in the posterior projection of the aggregate form; solitary form with eight (rarely nine) body muscles of which M I–IV are either fused, joined by muscle strands, touch, or approach one another dorsally; body muscles may be split into branches laterally, sometimes are fused laterally, thus tending to vary considerably; no attachment organs in the solitary form (excluding lips and cloacal siphon); test of the solitary form (in POFI specimens) bears a varying number of thickened white patches that are arranged in rows; or, according to Brooks (1893), Sewell (1926), and Stiasny (1926), there are seven longitudinal ridges on the test—two dorsal, two lateral, and three ventral, with a posterior ridge joining the midventral ridge.

I regard *Salpa cylindrica* as sufficiently different from the other species of *Salpa* to be placed in a new genus, *Weelia*, named to honor Dr. P. B. van Weel of the University of Hawaii, who has contributed so significantly to the present study. The only known species, *Weelia cylindrica*, is the type.

Weelia cylindrica (Cuvier) 1804

Figs. 16*c*, 17*a–f*

Salpa cylindrica Cuvier, 1804: 381; Bomford,

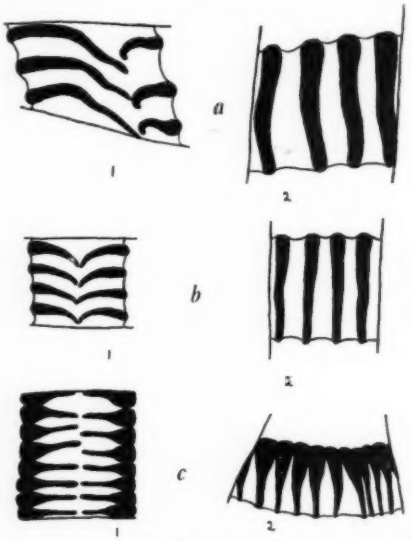

FIG. 16. Diagrams of a part of the gill bar of the solitary form. *a*, *Salpa maxima*; *b*, *Salpa fusiformis*; *c*, *Weelia cylindrica*. 1, ventral aspect; 2, lateral aspect.

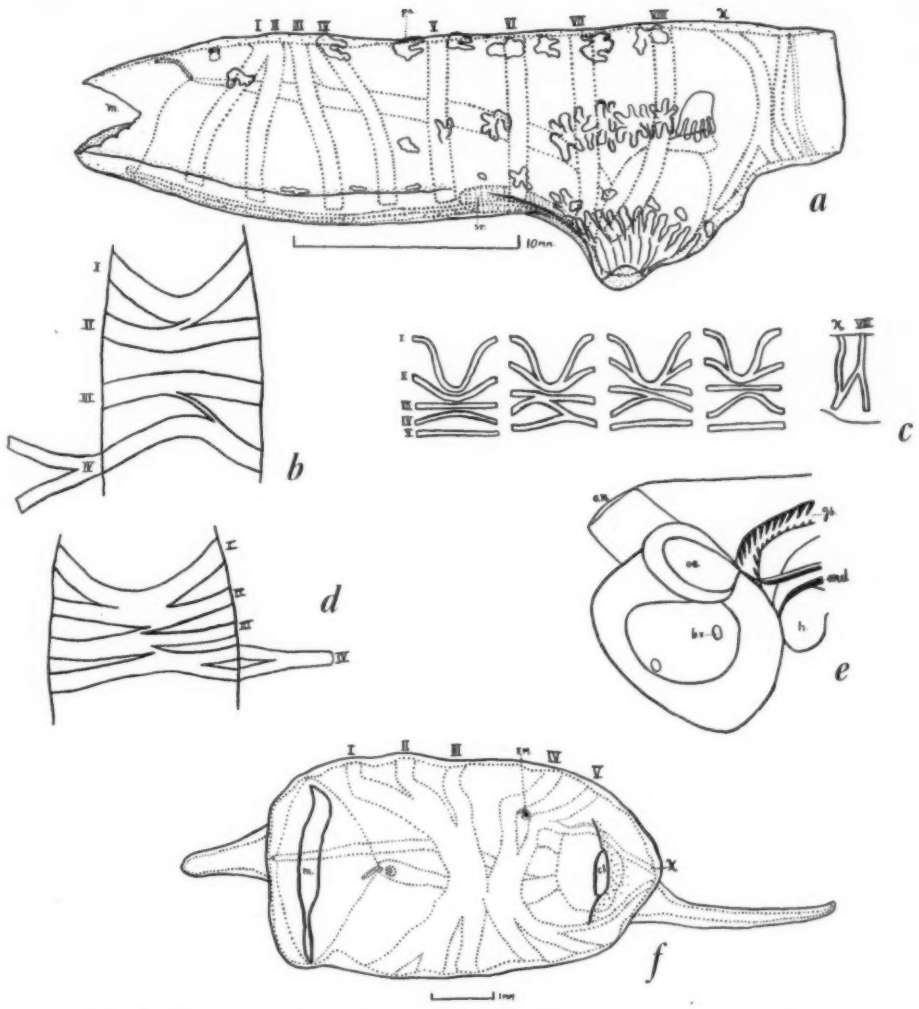

FIG. 17. *Weelia cylindrica*. *a*, Solitary form, left side; *b,c,d*, diagrams of muscle variation in the solitary form; in *b* and *d*, M IV is represented as being drawn out on one side (*c* after Sewell, 1926); *e*, gut of solitary form, right side; *f*, aggregate form, dorsal aspect.

1913: 243; Oka, 1915: 31; Ihle, 1935: 527–529; Tokioka, 1937: 223; Thompson, 1948: 161.

Iasis cylindrica Savigny, 1816: 235.

Salpa coerulescens Chamisso, 1819: 22.

Salpa elongata Blainville, 1827: 113.

Salpa garnotti [?] Lesson, 1830: 271.

Salpa truncata [?] Quoy and Gaimard, 1834: 588.

Salpa coerulea Quoy and Gaimard, 1834: 589.

Salpa (*Salpa*) *cylindrica* Metcalf, 1918: 93; Sewell, 1926: 77; Stiasny, 1926: 429.

SOLITARY FORM: Over 10 specimens examined with a length range of 14–38 mm. (Fig.

17*a*). *Test:* Glutinous, dorsally and laterally thin, ventrally thickened especially over the gut as gut swelling; from anterior point of gut swelling, two weak ridges lacking spines coursing shortly anteriorly and posteriorly on ventral surface of gut swelling; anteriorly a sparsely spined ridge encircling base of ventral lip; chin weakly developed; attachment organs absent; a varying number of white patches of thickened test most prominent posteriorly, especially over the gut, arranged in three rows on each side: (1) a dorsolateral row, (2) a lateral row, and (3) a ventrolateral row at edge of thickened ventral test continuing with patches over gut. *Muscles:* Eight (sometimes nine, as described by Sewell, 1926) body muscles, some of which may divide into two branches laterally; M I–IV approaching, fusing, or joining by means of fine strands of muscle dorsally, varying considerably (Fig. 17*b–d*); remainder of muscles usually equally separate from ane another except x, which may approach M VIII dorsally; all body muscles extend rather far ventrally; some may be fused, but usually are separate. *Ciliated groove:* Simple, elongate, straight or slightly bent. *Viscera:* Gut compact, in condition E of Ihle and Ihle-Landenberg (1933) (Fig. 17*e*); stolon club-shaped, straight (or undulating according to Thompson, 1948); transverse ribs of gill touching one another dorsolaterally; tapering sharply and becoming rather far separated ventrally. In species of *Salpa*, these ribs are separate along their entire length and taper gradually toward the ventral surface (Fig. 16).

AGGREGATE FORM: Over 10 specimens examined, with length range of 6–16 mm. (Fig. 17*f*). *Test:* Flabby, without permanent ridges or grooves; one anterior and one posterior asymmetric projection, which are usually short and stumpy, but may be elongate as in Fig. 17*f*. Eight attachment organs present according to Stiasny (1926), but only six were visible in POFI specimens. *Muscles:* Five body muscles; M I–III fused dorsally as are M IV and V; in all POFI specimens the two groups are joined dorsally (but may be distinct, according to other investigators); muscles extending rather far ventrally. *Ciliated groove:* Slightly arched, simple. *Viscera:* Gut compact, in condition E of Ihle and Ihle-Landenberg (1933); embryo on right side between M IV and V; gill as in solitary form.

This salp has been studied by many investigators, but only Brooks (1893) and, especially, Sewell (1926) have shown any of the great variation in muscle arrangement that occurs in the solitary form. The usual descriptions point out only that M I–IV approach or touch dorsally, the rest remain separate. The actual muscular arrangement may differ considerably from this condition (Fig. 17*b–d*). In regard to the test of the solitary form, Brooks (1893), Sewell (1926), and Stiasny (1926) described seven longitudinal ridges—two dorsal, two lateral, and three ventral—as well as a posterior ridge. In all specimens I have examined, however, there are only two longitudinal ventral ridges present, and they are much shorter than those described by the above-named investigators. Evidently, there is also a rather large amount of variation in test structure. Almost all specimens, both aggregate and solitary, in the POFI collections are separated from their tests. In only a few individuals did the tests remain on the animals. I was unable to find the ridges described by Stiasny (1926) on the test of the aggregate form.

Genus RITTERIELLA Metcalf, 1919

Solitary form with 10 to 24 body muscles, all of which are ventrally interrupted, except in *R. amboinensis* the first three or four form complete rings. Aggregate form with six body muscles that form groups dorsally. Transverse ridges of gill bar are separated from one another by a distance greater than 0.5 the width of the gill bar. Solitary form possesses a blood-forming organ.

Two species, *Ritteriella amboinensis* (type) and *R. picteti*.

R. picteti and *R. amboinensis* were first de-

scribed by Apstein (1904) from Amboina. In 1906, Ritter described what he regarded as a new species, *Cyclosalpa retracta* (= *R. retracta*). This, however, was regarded by Ihle (1910) as similar enough to *R. picteti* to be a doubtful species if an intermediate form were found. Komai (1932) described such an intermediate form, so that at present *R. retracta* is considered a synonym of *R. picteti*.

Ritteriella amboinensis (Apstein) 1904
Fig. 18*a–c*

Salpa amboinensis Apstein 1904: 651; 1906*b* (agg.): 166; Ihle, 1910: 34; 1912: 44.

Salpa (*Ritteria*) *amboinensis* Metcalf, 1918: 56; Sewell, 1926: 85.

Ritteriella amboinensis Ihle, 1935: 527–529; Tokioka, 1937: 222; Thompson, 1948: 126.

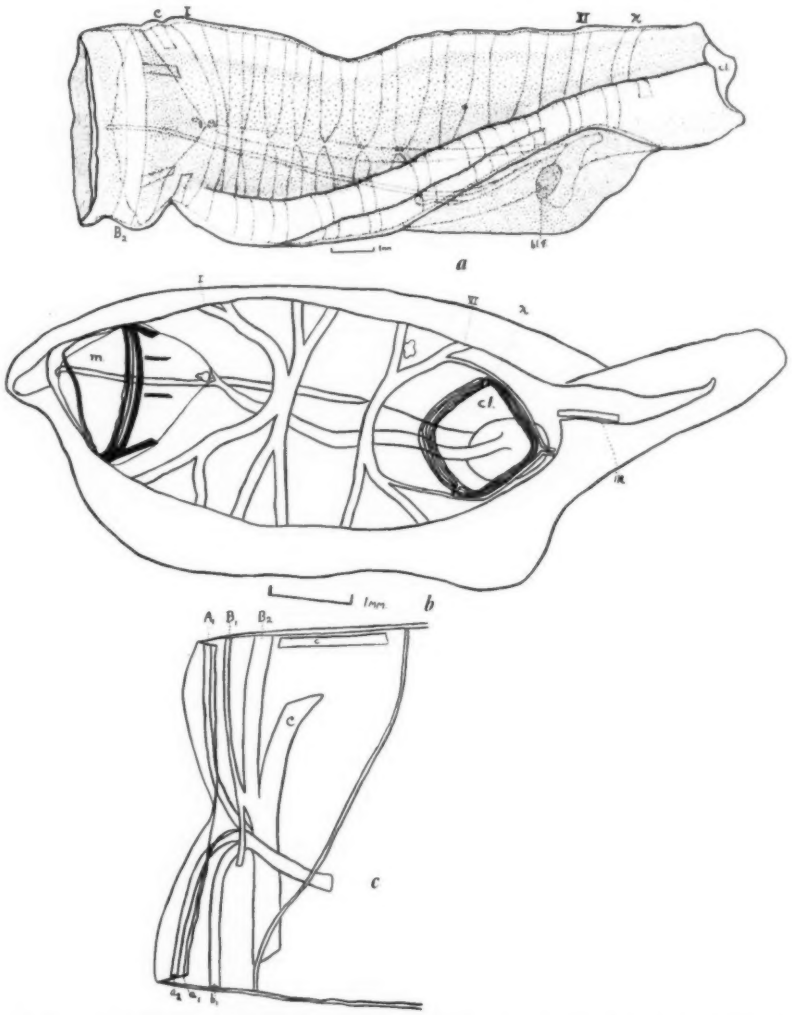

FIG. 18. *Ritteriella amboinensis*. *a*, Solitary form, dorsolateral aspect; *b*, aggregate form, dorsal aspect; *c*, aggregate form, mouth musculature of right side from inside.

[non] *Salpa amboinensis* Apstein, 1906*a:* 250; 1906*b* (sol.): 166.

SOLITARY FORM: Over 10 specimens examined with length range of 3 (embryos)–29 mm. (Fig. 18*a*). *Test:* Flabby, thin, especially over muscles; a rather thick, elongate gut swelling; there may be an additional swelling immediately over gut; no other permanent elevations or depressions. *Muscles:* Number of body muscles varies from 10 to 13, usually 11 or 12; number of muscles may be different on opposite sides of the body; M I–III touching dorsally as do X–XI and x; third upper lip sphincter muscle (B_2) distinct, large, continuous dorsally and ventrally; bow muscle interrupted dorsally, continuous ventrally; M I–III or IV forming rings; remainder of body muscles interrupted ventrally, becoming more widely interrupted posteriorly; all body muscles except I, II, X, and XI are joined dorsally by connecting bands of muscle; muscles relatively opaque and rather iridescent in all specimens examined. *Ciliated groove:* Simple, forming a crescent similar to that of *S. fusiformis* sol. *Viscera:* Gut rather compact, in condition A (Ihle and Ihle-Landenberg, 1933); stolon segmented only far anterior to gut, turning posteriorly at region of M V; a round or bean-shaped blood-forming organ present on left side of gut.

AGGREGATE FORM: Six specimens examined with a length range of 6–10 mm. (with projections) (Fig. 18*b,c*). *Test:* Flabby, glutinous; thin over whole body, slightly thicker over gut forming a rounded bulge; a general swelling of test material in gut area; end projections asymmetric, posterior one long, club-shaped, anterior one short, blunt. *Muscles:* Six body muscles of which M I–II and III–IV join dorsally into a group as do M V–VI; M I–II widely fused dorsally; all extend far toward the endostyle ventrally; a large, rather prominent independent muscle (*in*) on the posterior end projection under gut swelling, on right or left side according to position of animal on the stolon; this muscle much longer and more prominent than in any species of *Salpa;* M A_1 continuous dorsally; three ventral lip sphincters present. *Ciliated groove:* Situated vertically or almost so, a simple open structure. *Viscera:* Gut compact, in state D of Ihle and Ihle-Landenberg (1933); ribs or segments of gill bar relatively far separated; embryo attached beneath M V on right dorsal body wall.

Ritteriella picteti (Apstein) 1904
Fig. 19*a–f*

Salpa picteti Apstein, 1904: 655; 1906*a:* 252; 1906*b:* 168; Ihle, 1910: 43; 1912: 46.
Cyclosalpa retracta Ritter, 1906: 1.
Salpa amboinensis Apstein 1906*a:* 250; 1906*b:* 166.
[non] *Salpa amboinensis* Apstein, 1904: 651.
Salpa retracta Ihle, 1910: 40; 1912: 45.
Salpa (*Ritteria*) *retracta* Metcalf, 1918: 53.
Salpa (*Ritteria*) *picteti* Metcalf, 1918: 55; Sewell, 1926: 86.
Salpa (*Ritteriella*) *picteti* Komai, 1932: 65.
Ritteriella picteti Ihle, 1935: 527–529; Tokioka, 1937: 222; Thompson, 1948: 124; Berner, 1954.

SOLITARY FORM: Over 10 specimens examined with length range of 21–86 mm. (Fig. 19*a,b*). *Test:* Moderately thick over whole body with a slight elevation over the gut region; flabby and glutinous; no permanent elevations and depressions except over gut (Figure 19*a* represents an unusual condition in which there is present one lateral depression on each side; usually there is a single dorsal depression and no lateral ones). *Muscles:* Number varying from 13 to 24, including x and y, in the POFI specimens; number of muscles on one side usually different from number on opposite side; all body muscles continuous dorsally, interrupted ventrally; M I–V or VI usually connected by bands of muscle, remainder may be connected or distinct. *Ciliated groove:* Elongate, sinuous, but simple. *Viscera:* Gut in condition G (Ihle and Ihle-Landenberg, 1933), T-shaped with esophagus and

caecum forming right and left parts, respectively, of head of T, intestine forming posterior shaft of T; elongate, cylindrical, blood-forming organ located on left side, projecting from region of caecum dorsally, then bending anteriorly (abnormally posteriorly as in the figured specimen); stolon forming a slight bend and turning posteriorly at region of M VI–VIII.

AGGREGATE FORM: Two specimens examined, with length range of 18–23 mm., without end projections (Fig. 19*c–f*). *Test:* Flabby, glutinous, without permanent elevations and depressions except gut swelling which forms a large protrusion almost wholly independent of the rest of the body; end projections asymmetric, filiform. *Muscles:* Body muscles closely similar to those of *R. amboinensis* except wider and composed of more fibers (Berner, 1954); three sphincters in dorsal lip, of which the

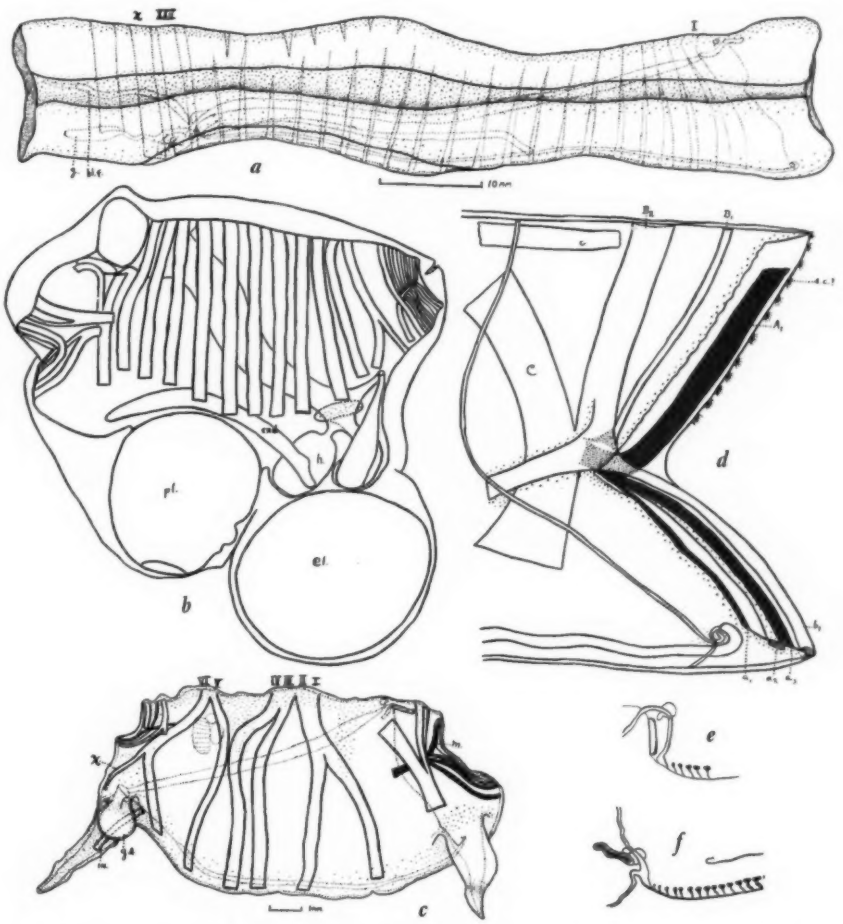

FIG. 19. *Rstteriella picteti*. *a*, Solitary form, right side; *b*, solitary form, left side of embryo (length, 1.3 mm.); *c*, aggregate form, right side; *d*, aggregate form, mouth musculature of left side from inside; *e*, aggregate form, ciliated groove, lateral aspect; *f*, aggregate form, ciliated groove, ventral aspect.

first is interrupted middorsally, the remainder continuous, and four continuous ventral lip sphincters; independent muscle large and conspicuous. *Ciliated groove:* Similar to that of *R. amboinensis* agg. *Viscera:* Similar to that of *R. amboinensis*, except that the endostyle extends almost to the gut in *R. picteti*, whereas it extends only to the level of M V or less in *R. amboinensis*.

The solitary forms of *R. picteti* and *R. amboinensis* are rather similar to one another. Descriptions of them, however, vary considerably and should be reviewed, as there is much overlapping between descriptions and probable errors in them. All descriptions agree in regard to gut structure (except for those of Apstein [1906*a*, 1906*b*] who evidently mistakenly identified his specimens as *S. amboinensis*). Ihle (1910) restudied these specimens and considered them to be *S. retracta*. They had the characteristic T-shaped gut structure of *R. picteti*.

In regard to muscle structure, however, there are a large number of contradictions. All past descriptions except Apstein's (1904) of *R. amboinensis* described M I–III as ring muscles. Apstein, however, in first describing the species, stated that the anterior muscles coursed almost to the endostyle and were thus interrupted. Ihle (1910) restudied these specimens that Apstein had described and stated for *R. amboinensis* sol. that "die 3 vorderen Körpermuskeln ebenso wie die Bogenmuskel ringförmig sind."

Sewell (1926), although not describing the condition, figured in *R. amboinensis* sol. M I–IV as ring muscles; in most POFI specimens here examined, M I–IV are ring muscles; in some specimens, only M I–III are rings.

Ritter (1906) emphasized the fact that in his specimen of *Cyclosalpa retracta* (=*R. picteti*), M 2–10 were completely continuous ventrally, thus ring muscles. This has not been observed in any other specimen of the species.

Apstein (1906*a*) described specimens, regarded by him as *S. amboinensis*, as possessing four "vollkommene Rundmuskeln," although in his earlier description (1904) of *S. amboinensis* all body muscles were considered to be ventrally interrupted. Ihle (1910) restudied these specimens that Apstein (1906*a*) had studied and identified them as *S. retracta*. He stated that with this species all body muscles were ventrally interrupted. Later, however, Ihle (1912) described the species *S. retracta* as follows: "Vordere Muskeln ringförmig. . . ."

In specimens of *R. picteti* described by Apstein (1904), Ihle (1910), Sewell (1926), Komai (1932), and Thompson (1948), all body muscles were described as ventrally interrupted. Apstein later (1906*a*, 1906*b*) made no mention of this condition even though he had done so in 1904. Ihle (1912), however, stated in regard to *R. picteti*, "Vordere Muskeln medio-ventral geschlossen." Also, Ihle (1935) characterized the genus *Ritteriella* as possessing 9–24 body muscles of which the "vorderen ringförmig sind."

Komai (1932) described a specimen of *R. picteti* in which all body muscles were ventrally interrupted. In regard to Ritter's (1906) description that *C. retracta* possessed nine ring muscles, Komai stated, "It is very doubtful whether one can put so much importance on that feature of the musculature in *R. retracta*, even if Ritter's observation on this point is warranted." I cannot agree with this statement, but rather believe that inconsistencies described have been the result of mistakes on the part of the observers. My conclusion is upheld by the POFI embryo, in which all body muscles and M C are ventrally interrupted.

The blood-forming organ of *R. amboinensis* has been described only as round or bean-shaped. In *R. picteti* (and *S. retracta*) it has usually been described as elongate, but Ihle (1910) described that of *S. picteti* as bean-shaped and that of *S. retracta* as variable in structure. Thus, this character perhaps is not important systematically.

Descriptions of the stolon also vary considerably. In *R. picteti* it varies from a spiral

(Apstein, 1906*a*, identified by him as *S. amboinensis*) to an elongate vermiform structure with a slight bend; in *R. amboinensis* it forms a wide sickle-shaped curve or is straight but may be slightly spiralled; thus, this organ also is perhaps not important systematically.

It is obvious from the literature that there has been a considerable amount of confusion in identifying the two solitary forms. Also obvious, both from the literature and POFI specimens, is the fact that these forms have a wide range of variability, perhaps more than any other salp, especially in muscle number and condition. I believe, however, that the differences in gut structure and in interruptions of the body muscles are important and valid differences. They are applicable to all POFI specimens, at any rate, except for the gut of the embryo of *R. picteti*.

The gregarious form of *R. amboinensis* has long been known (but that of *R. picteti* has only recently been described) by Berner (1954). Apstein (1904) first described the aggregate form of *R. amboinensis* rather inadequately, not describing the mouth or cloacal muscles. His figure does not permit accurate identification. Ihle (1910) studied this form next, describing both older chain forms and very young stolonic individuals. His descriptions are thorough and adequate for identification of *R. amboinensis* agg. He described and figured three sphincters in each lip (Taf. I, fig. 10) of the chain specimens. All these sphincters were described as uninterrupted. Metcalf (1918) based his description completely on that of Ihle (1910). He reproduced Ihle's figure 10 among others, thus showed *three* sphincters in each lip; but he described it as follows: "The oral muscles (Fig. 31) include a retractor and, in the upper and lower lips, two sphincters each. . . ." It may be thought that he considered the finer sphincters as only branches of one main sphincter, thus two in each lip, but in his other descriptions, each mouth muscle, no matter how small, was distinguished by a name and number. Therefore, he obviously misread Ihle (1910) and, although reproducing Ihle's figure correctly, he described the animal incorrectly. Thompson (1948) based most of his descriptions on those of Metcalf (1918) and repeated Metcalf's error in the description of *R. amboinensis* agg. Thompson's figure shows only two sphincters in each lip, but as the figure is of the whole animal, details were probably overlooked in the mouth musculature. He also reproduced Ihle's figures (1910) but described the animal inaccurately, although Ihle had clearly labeled the three sphincters in each lip.

Berner (1954) identified the aggregate form of *R. picteti* by the embryo held within them and distinguished the form chiefly by the following features: (1) the body muscles are composed of more fibers and are thus wierd, and (2) the lip muscles of *R. picteti* include three sphincters in each lip, whereas there are only two in *R. amboinensis*. He apparently carried on the error of Metcalf and Thompson in his statement that the aggregate form of *R. amboinensis* has two sphincters in each lip.

I have found two specimens of the aggregate form of *R. picteti* in the POFI collections as well as six specimens of *R. amboinensis* and thus have been able to make a thorough comparison.

The major differences noted are:

1. *R. picteti* possesses three dorsal lip sphincters (A_1, B_1, B_2) and four ventral lip sphincters (a_1, a_2, a_3, b_1), one of which, a_2, remains hidden beneath the more conspicuous a_3; in *R. amboinensis* there are three dorsal lip sphincters, one of which, B_1, is very small and thus inconspicuous, and the ventral lip also contains three.

2. As Berner (1954) showed, in *R. picteti* upper-lip sphincter 1 (A_1) is interrupted middorsally, whereas in *R. amboinensis* it is continuous.

3. The gut swelling of *R. picteti* is conspicuous and almost completely independent of the remainder of the body (as described in some specimens by Ihle, 1910; thus, if this

proves to be a useful difference, Ihle may have examined some specimens of *R. picteti* agg.), whereas in *R. amboinensis* it projects only slightly and is not independent of the remainder of the test.

4. The posterior end projection of *R. amboinensis* is large and club-shaped, whereas that of *R. picteti* is small and almost filiform.

5. The anterior end projection is short and blunt in *R. amboinensis*, whereas it is moderately long and filiform in *R. picteti*. Thus, if these last three differences are universal, these species deviate somewhat from the usual condition in salps in that the test is soft (but permanent structures are apparently present) and yet is useful in species distinction.

6. The endostyle extends further posteriorly in *R. picteti* than in *R. amboinensis*.

Both specimens of *R. picteti* contained embryos recognizable as this species, but the gut was not yet extended (Fig. 19*b*). No specimens of *R. amboinensis* contained embryos old enough to show structures nearing adult condition. The largest of these latter embryos (length, 0.3 mm.) contained nine recognizable body muscles, each of which, however, was widely interrupted dorsally and ventrally. A study of a nearly mature embryo from an aggregate *R. amboinensis* is thus desirable.

Genus METCALFINA Ihle and Ihle-Landenberg, 1933

Solitary form with 10–13 asymmetric, ventrally interrupted body muscles; these are all joined dorsally. Aggregate form with six ventrally interrupted body muscles, of which M V and VI are independent from other body muscles. Test of both forms is firm and bears serrated ridges.

One species, *Metcalfina hexagona*.

Metcalfina hexagona (Quoy and Gaimard) 1824

Figs. 20*a–d*, 21*a–d*

Salpa hexagona Quoy and Gaimard, 1824: 505; Bomford, 1913: 244; Oka, 1915: 30.
Salpa triangularis [?] Quoy and Gaimard, 1824: 511.
Salpa biensis [?] Blainville, 1827: 123.
Salpa lineata [?] Lesson, 1830: 268.
Salpa monotoma [?] Quoy and Gaimard, 1834: 591.

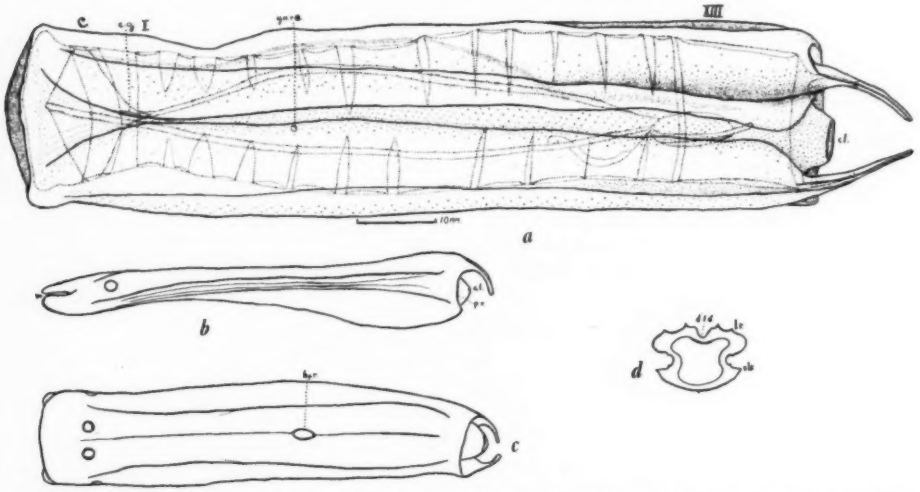

FIG. 20. *Metcalfina hexagona*, solitary form. *a*, Whole animal, dorsal aspect; *b*, test, left side; *c*, test, ventral surface; *d*, schematic cross section of test at level of ganglion.

Salpa (*Jasis*) *hexagona* Apstein, 1894*a:* 52.

Jasis hexagona Heider, 1895: 368.

Salpa (*Ritteria*) *hexagona* Metcalf, 1918: 62; Sewell, 1926: 87.

Metcalfina hexagona Ihle and Ihle-Landenberg, 1933: 199; Ihle, 1935: 527–529; Thompson, 1948: 129.

SOLITARY FORM: More than 10 specimens examined with length range of 48–117 mm. with end projections (Fig. 20). *Test:* Traustedt (1885) figured the test accurately; unfortunately, his figures were not copied completely by Apstein (1906*b*), Metcalf (1918), and Thompson (1948), who left out the test ridges so well shown by Traustedt. The description of the test here agrees with that of Traustedt, but he did not figure or describe the attachment organs described here. Test firm; one posterior projection on each side that contains a mantle process which bears a sucker on its tip. As Sewell (1926) pointed out, there are on each posterior projection five [minutely serrated] ridges. They are symmetrically located—one dorsal, two lateral, and two ventral. The lateral ridges of the projections are continuous with the posterior ridge of test encircling the cloacal siphon ventrally. There are 11 longitudinal ridges—four dorsal, six lateral, and one ventral (or four lateral and three ventral)—and one circular posterior ridge around the cloacal region ventrally, continuous with the posterior projections. In small specimens, all these ridges bear small or minute spines. In large specimens the spines are sparse and always minute. Chin and gut swelling moderately large. Attachment organs are relatively numerous on this solitary form; one disappears in the largest specimens. There are two anteroventral attachment organs at base of chin; a third, midventral and anterior to gut region, interrupts mid-

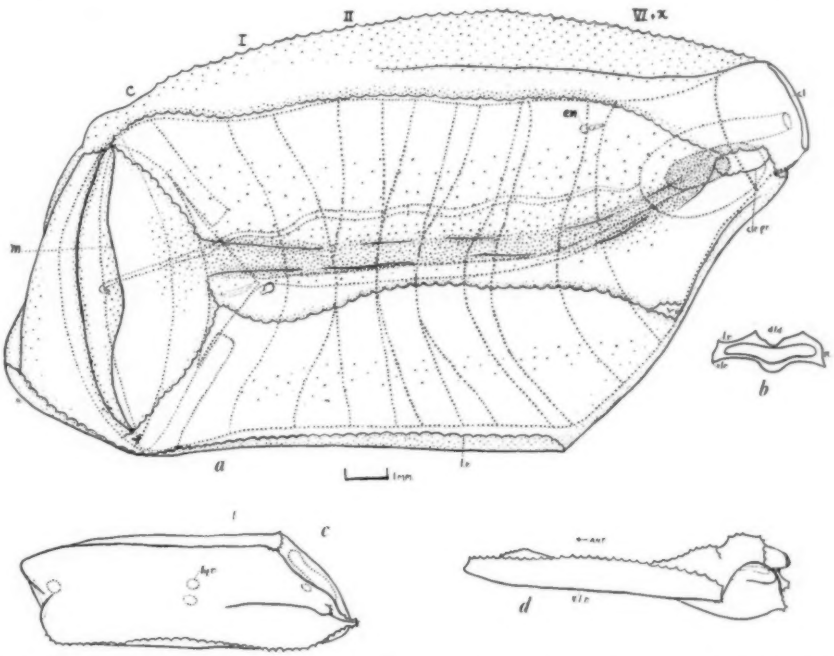

FIG. 21. *Metcalfina hexagona*, aggregate form. *a*, Whole animal, dorsal aspect; *b*, scheme of cross section of the test at M III level; *c*, test, ventral aspect; *d*, test, left side.

ventral ridge; it is absent in largest specimens; one lateral attachment organ on each side just behind angle of mouth. *Muscles:* Number varies, in POFI specimens ranging from 10 on one side and 11 on the opposite side to 12 and 13, respectively; muscles usually unequal in number on opposite sides; in POFI specimens, all body muscles irregularly continuous dorsally and connected dorsally by muscle strands except the last one, all interrupted rather widely ventrally (according to the figures of Traustedt, 1885, and Thompson, 1948, however, M I and II are distinct muscle bands); the last muscle much broader than other muscles; M C broad, continuous dorsally, widely interrupted ventrally. *Ciliated groove, ganglion and eye:* Ciliated groove elongate, straight, simple, located between M I and M C or under M C; ganglion and eye located far posteriorly, under M IV or V; eye a modified horseshoe (see Metcalf, 1918, fig. 39) with pigment at base and at each tip. *Viscera:* Gut moderately compact, in condition E (Ihle and Ihle-Landenberg, 1933); stolon forming a weak spiral, coursing anteriorly, bending and coursing posteriorly on left side of gut.

AGGREGATE FORM: More than 10 specimens examined with length range of 2 (stolon individual)–41 mm. (Fig. 21). *Test:* As with the solitary form, the aggregate form has been figured well by Traustedt (1885), Brooks (1893), and Apstein (1894*b*). Traustedt's figure, unfortunately, is of a dissected specimen, thus does not show the dorsal surface of the test. Test firm, asymmetric; middorsal depression thin, limited by weak grooves; dorsal limiting ridges on either side of depression, one always farther away from dorsal depression than other; these ridges continuing anteriorly into a circular ridge ringing the mouth widely; circular ridge on this side continuing posteriorly as lateral ridge ending after turning ventrally near level of gut; a prominent circular projection posteriorly over gut, flat on top and ridged; gut swelling and chin prominent; ventrolateral ridge not serrated except on posterior tip (no equivalent ridge on opposite side of body); on opposite side a ventrolateral ridge (equivalent to lateral ridge above), serrated; in ventral view, a prominent midventral ridge over gut swelling disappearing anteriorly, forming a small posterior projection; all ridges mentioned except ventrolateral ridge on one side (left side in figures) and midventral ridge rather strongly serrated; thus six longitudinal ridges, one anterior circular one, and one posterior one below the cloacal siphon; attachment organs usually six—one large one at each end, one smaller circular one just anterior and posterior, respectively, to the latter, and two smaller circular ones midventrally. *Muscles:* Six body muscles, all interrupted ventrally, continuous dorsally; M I–IV forming a group dorsally, M V and VI independent; M V wider than first four, M VI much wider than V; M C broad, anterior part continuous middorsally; posterior part branching off from latter, interrupted dorsally. *Ciliated groove:* Moderately elongate, simple. *Viscera:* Gut compact, in condition E (Ihle and Ihle-Landenberg, 1933); endostyle sinuous; two to five, usually four embryos present.

Genus THETYS Tilesius, 1802

Solitary form with 16–22, aggregate form with 5, weakly developed body muscles which are widely interrupted ventrally. Some of them are also laterally interrupted. Test firm, with many large spines over surface but without serrated ridges.

One species, *Thetys vagina*.

Thetys vagina Tilesius, 1802
Figs. 22*a–d*, 23*a–d*

Dagysa notata [part.] Gmelin, 1791: 3131.
Thetys vagina Tilesius, 1802: 150; Ihle, 1935: 527–529; Tokioka, 1937: 224; Thompson, 1948: 136.
Salpa tilesii Cuvier, 1804: 375.
Dagysa strumosa Home, 1814: 71.
Salpa costata Quoy and Gaimard, 1824: 504.

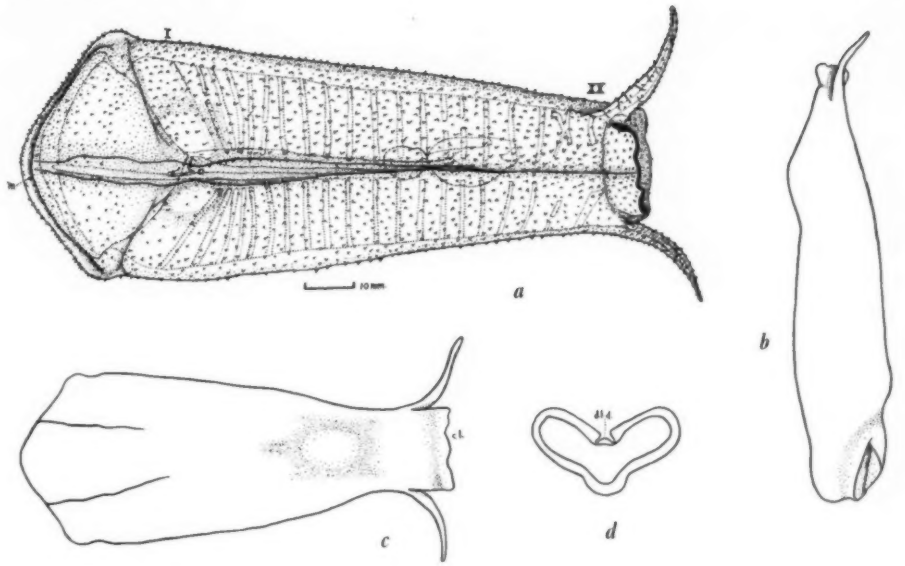

FIG. 22. *Thetys vagina*, solitary form. *a*, Whole animal, dorsal aspect; *b*, test, right side; *c*, test, ventral surface; *d*, schematic cross section of the test at gut level.

Salpa bigibbosa Quoy and Gaimard, 1824: 505.
Salpa gibbosa Quoy and Gaimard, 1824: 506.
Salpa infundibuliformis Quoy and Gaimard, 1824: 508.
Salpa costata-tilesii Traustedt, 1885: 379; Oka, 1915: 30.
Salpa sp. (?) n. sp. [?] Herdman, 1888: 62.
Jasis tilesii Lahille, 1890: 11.
Salpa (*Jasis*) *costata-tilesii* Apstein, 1894*a:* 50.
Salpa tilesii-costata Ritter, 1905: 70.
Salpa vagina Ihle, 1911: 587.
Salpa (*Thetys*) *vagina* Metcalf, 1918: 121; Sewell, 1926: 98; Stiasny, 1926: 446; Berrill, 1950: 299.

SOLITARY FORM: One specimen examined with length of 123 mm. without projections (Fig. 22). *Test:* Firm and thick except on inturned lips and on cloacal siphon; large spines occuring irregularly over whole surface; a prominent posterior projection on each side of cloacal siphon, containing tube of mantel epithelium with no sucker; dorsal depression limited by a groove on each side of a raised middle region, the whole limited by broad limiting elevations; shallow lateral depression; midventral elevation raised over gut and chin as swellings; transverse groove at base of dorsal lip, continuing laterally to angle of mouth; one swelling on each side of dorsal surface posterior to transverse groove; base of ventral lip with a weak circular depression; transverse groove at base of cloacal siphon; one short, weak, longitudinal depression crossing each side of chin ventrally. *Muscles:* Twenty weakly developed muscles (number varies from 16 to 22 according to Thompson, 1948); all interrupted dorsally and ventrally, often elsewhere, accompanied by prominent blood vessels; muscles not extending to ventral surface, but blood vessels do; M I–IV or VI converge dorsally. *Ciliated groove:* Forming a large open loop. *Viscera:* Gut large, compact, in state E (Ihle and Ihle-Landenberg, 1933); located far anteriorly, at about the posterior third of body; endostyle broad, straight; stolon coursing anteriorly, bending and coursing posteriorly on left side of gut (Traustedt, 1885).

AGGREGATE FORM: Seven specimens examined with length range of 33–71 mm. (Fig. 23). *Test:* Asymmetric, thick and firm except on lips and cloacal siphon; dorsal depression broad, extending from dorsal lip to above cloacal siphon; a broad dorsal limiting elevation on each side; transverse groove at base of dorsal lip; other transverse grooves and folds occuring incidentally over test; lateral depression shallow or forming deep grooves; ventral surface greatly thickened, especially over chin and gut swelling; large spines with a rather constant arrangement over test according to animal's location on the stolon; three longitudinal rows on dorsolateral elevation of one side, one row extending posteroventrally onto gut swelling; gut swelling with few spines on posteroventral region; on opposite side of test, two longitudinal rows on dorsolateral elevation continuing anteroventrally with a group of spines crossing lateral depression, extending onto chin; several spines present on posterodorsal and posteroventral regions of gut swelling; one group of spines extending transversely over dorsal lip; scattered spines in middorsal depression. Number of attachment organs varies, asymmetric in arrangement. *Muscles:* Five body muscles, interrupted dorsally and ventrally, extending only to sides of body; weakly developed, being interrupted in various places; M I–III converging dorsally but not touching; M V bifurcates; prominent blood vessels accompanying muscles. *Ciliated groove:* A large open loop. *Viscera:* Gut compact, in state E (Ihle and Ihle-Landenberg, 1933); endostyle narrow, sinuous; three or four embryos attached dorsally between M IV and V (Thompson, 1948).

Except for *Helicosalpa komaii* (230 mm.), the solitary form of this species is the largest of the salps (up to 226 mm. according to Traustedt, 1885). It was well figured (solitary form) by Traustedt (1885) and Stiasny (1926).

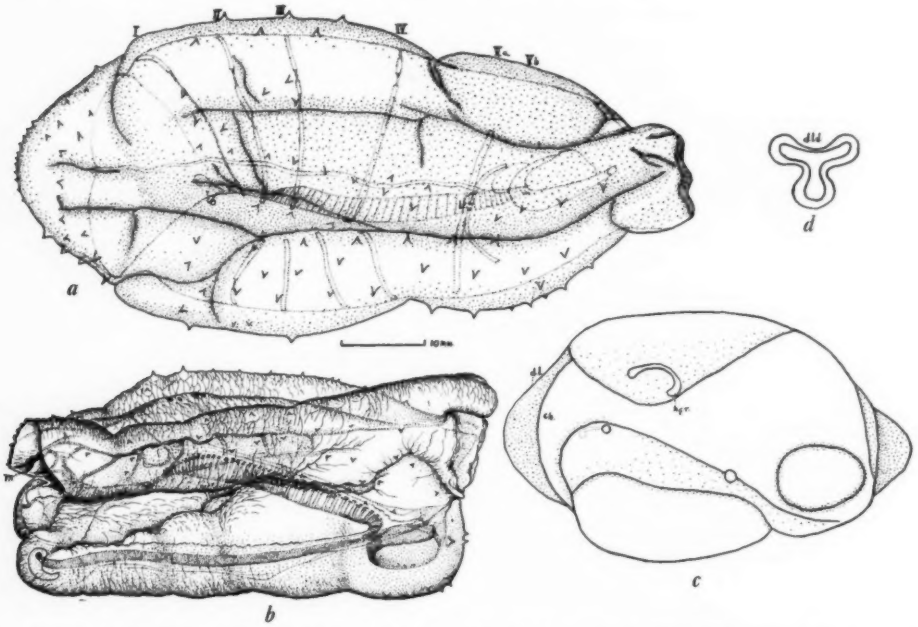

FIG. 23. *Thetys vagina*, aggregate form. *a*, Whole animal, dorsal aspect; *b*, another specimen, lateral aspect (length, 38 mm.); *c*, same specimen as *a*, ventral aspect of test; *d*, schematic cross section of test at level of M III.

The stolon individual (aggregate form) was well figured by Traustedt (1885) and Tokioka (1937). The preceding description (solitary form) agrees with their reports except for minor details.

Genus PEGEA Savigny, 1816

Four ventrally interrupted body muscles in both forms. Aggregate form with eight prominent, symmetrically arranged attachment organs.

One species, *Pegea confoederata*.

Pegea confoederata (Forskål) 1775
Figs. 24, 25

Salpa confoederata Forskål, 1775: 115; Bomford, 1913: 244.
Biphora confoederata Bruguière, 1789: 181.
Salpa gibba [?] Bosc, 1802: 178.
Salpa socia Bosc, 1802: 180.
Salpa scutigera Cuvier, 1804: 577.
Salpa octophora Cuvier, 1804: 577.
Salpa vivipara [?] Péron and Lesueur, 1807: pl. 31, fig. 3.
Pegea octofora Savigny, 1816: 235.
Salpa ferruginea Chamisso, 1819: 23.
Salpa informis Quoy and Gaimard, 1824 [*fide* Thompson, 1948].
Salpa bicaudata Quoy and Gaimard, 1827: 225.
Salpa laevis [?] Lesson, 1830: 273.
Salpa nephodea [?] Lesson, 1830: 275.
Salpa dolium [?] Quoy and Gaimard, 1834: 575.
Salpa femoralis [?] Quoy and Gaimard, 1834: 577.
Salpa scutigera-confoederata Traustedt, 1885: 362; Oka, 1915: 31.
Salpa quadrata Herdman, 1888: 84.
Pegea confoederata Lahille, 1890: 11; Ihle, 1935: 527–529; Tokioka, 1937: 230; Ihle and Ihle-Landenberg, 1938*a:* 107; Thompson, 1948: 143.
Salpa (*Pegea*) *scutigera-confoederata* Apstein, 1894*a:* 42.
Salpa (*Pegea*) *scutigera-confoederata* forma *bicaudata* Apstein, 1894*a:* 43.
Salpa confoederata-scutigera Ritter, 1905: 80.
Salpa (*Salpa*) *confoederata* Streiff, 1908: 32.
Salpa (*Pegea*) *confederata* Metcalf, 1918: 127; Berrill, 1950: 297.
Salpa (*Pegea*) *confederata bicaudata* Metcalf, 1918: 139.
Salpa (*Pegea*) *confoederata* Sewell, 1926: 100; Stiasny, 1926: 448.

SOLITARY FORM: More than 10 specimens examined with length range of 14–85 mm. (Fig. 24). *Test:* There are two different forms of this animal, the one characteristic of larger specimens, the other of smaller specimens. In the large form, test usually pear-shaped, smaller posteriorly, thick on ventral surface, especially over gut; dorsally a broad, slightly thickened elevation extending from upper lip to cloacal opening; this elevation limited laterally by one dorsolateral groove on each side; test very thin and flabby on lateral surface, therefore with no permanent shape; a prominent ventral elevation limited on each side by a ventrolateral groove; gut swelling prominent, produced as an additional swelling over the elaeoblast; test in all specimens examined not spiny, but earlier investigators have noted serrations on some specimens. In the small form, test pear-shaped, thick all over, firm, smaller posteriorly than anteriorly; on dorsal surface a shallow depression or deep groove extending from upper lip to cloacal opening; this depression limited by dorsal elevations; laterally a shallow depression extending from angle of mouth almost to region of gut; ventrally a rather strong elevation extending from lower lip almost to cloacal opening; this elevation further raised over elaeoblast as a disc-like bulge and bearing a far anterior small circular depression in which is located an attachment organ. The smaller form agrees more closely to the type set up by Stiasny (1926), but individuals are often different from his type. Thus, this animal deviates from the conclusion set up earlier here; that is, even though its test is firm and there may be grooves (but no ridges), these grooves probably are not permanent, and a definite "type"

cannot be established for it. Stiasny (1926) figured and described a longitudinal depression midventrally, limited to the anterior part of the test. I have not seen such a depression on any of my specimens, but in all the smaller ones there is a small circular depression for an attachment organ, which perhaps is what he saw. This is absent in larger specimens. The elaeoblast is relatively much larger in smaller specimens but is always a much-flattened disc. *Muscles:* Four body muscles; M I and II converging dorsally as do M III and IV; laterally all muscles diverging from one another, thus forming two X-shaped figures dorsally; muscles short. *Ciliated groove:* A large vertical loop whose ends approach one another anteriorly. *Viscera:* Gut compact, in state H (Ihle and Ihle-Landenberg, 1938*a*); elaeoblast forming a disc beneath gut; stolon encircling gut closely; endostyle weakly sinuous; on each side of endostyle at level of gut, a row of raised projections which have been noticed only by Ihle and Ihle-Landenberg (1938*a*), who described them as "Falten des Pharynxbodens" (*f* in Fig. 24). (These are not present in the aggregate generation.)

AGGREGATE FORM: More than 10 specimens examined with length range of 4–48 mm. (Fig. 25). *Test:* Loose, flabby, thin except around gut swelling and occasional thickened regions; gut swelling prominent, bearing ridges or elevations above and below a circular longitudinal depression which is very shallow; ventral surface usually with a rather thickened narrow elevation; thin membranous sheets of test material may extend loosely out from gut swelling; in bicaudate specimens, two triangular extensions of test containing mantle epithelium extending dorsolaterally over gut swelling, one to each side of cloacal opening; on all specimens, two lateral and two ventral attachment organs on each side of body, making a total of eight; attachment organs tubular, prominent, symmetrical. Stiasny (1926) figured prominent ridges both ventrally and dorsally in addition to the gut ridges. My specimens do not agree with this; as the test is flabby, presence of depressions and elevations is considered here to be a matter of chance. The cloacal siphon forms a weak flap. *Muscles:* As in the solitary form, M I and II form an X-shaped group dorsally, as do M III and IV; they extend only to the lateral surface. *Ciliated groove:* Forming a large loop whose ends approach anteriorly. *Viscera:* Gut compact, in state C of Ihle and Ihle-Landenberg (1933); endostyle sinuous; embryo on right dorsal region between M III and IV.

The subspecies *bicaudata* of Metcalf (1918) is perhaps only a slight modification of the typical form. Sewell (1926) stated: "I

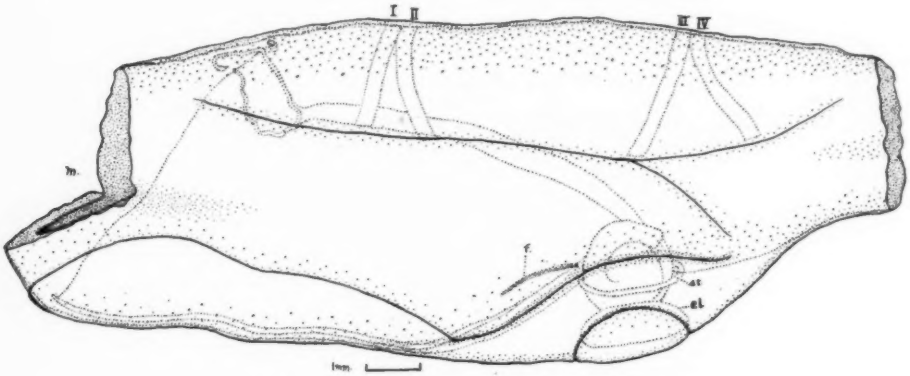

FIG. 24. *Pegea confoederata*, solitary form, left side.

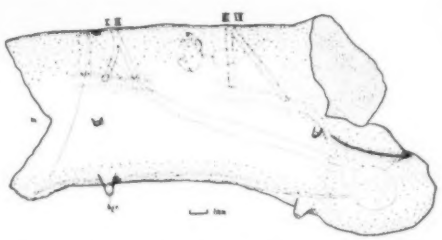

FIG. 25. *Pegea confoederata*, aggregate form, left side.

can see no justification for considering the *bicaudata* form to be even a variety, and much less a distinct subspecies, as Metcalf has done." Although I have seen only a few (all very small) specimens of this form, and thus little intergradation, Sewell's reckoning is considered probably correct here, and the bicaudate individuals are not given subspecific status.

Genus TRAUSTEDTIA Metcalf, 1918

Solitary form with 7 to 25 tentacles, aggregate form with two or three. Solitary form with five, gregarious form with four, body muscles that are widely interrupted ventrally.

One species, *Traustedtia multitentaculata*.

Traustedtia multitentaculata
(Quoy and Gaimard) 1834
Figs. 26*a–e*, 27*a–d*

Salpa multitentaculata Quoy and Gaimard, 1834: 596; Bomford, 1913: 244.
Salpa henseni Traustedt, 1893: 9.
Salpa verrucosa Apstein, 1894*b*: 12.
Salpa (*Traustedtia*) *multitentaculata* Metcalf, 1918: 147; Oka, 1921: 1; Sewell, 1926: 105.
Salpa (*Traustedtia*) *multitentaculata bicristata* Metcalf, 1918: 143.
Salpa (*Traustedtia*) *radiata* Metcalf, 1918: 152.
Salpa (*Traustedtia*) *henseni* Oka, 1921: 10–14.
Traustedtia multitentaculata Ihle, 1935: 527–529; Tokioka, 1937: 230; 1938: 234; Thompson, 1948: 147.

SOLITARY FORM: Five specimens examined with length range of 2–16 mm. (without projections) (Fig. 26*a*). *Test:* Thick, especially on crests, gut swelling, chin, and lips; in dorsal view, a raised median depression extending posteriorly to form the cloacal flap, anteriorly to the greatly thickened transverse ridges of the upper lip; continuing anterolaterally with a vertical elevation that joins its fellow of the opposite side midventrally under the chin; dorsal depression limited by grooves or depressions on each side which form the bases of the prominent dorsal limiting ridges (crests); crest covered with peculiarly shaped spines (see Fig. 26*c*, also Apstein, 1894, Taf. II, fig. 13), continuing with one break posteroventrally below and behind cloacal opening, meeting fellow of opposite side there; cloacal flap bearing a small projection on each side; each crest bearing a moderately long tentacle directed posteriorly; a posteroventral unpaired tentacle, which is doubtless the remains of the elaeoblast attachment as suggested by Thompson, projecting posteriorly; 10 other paired tentacles on posterior lateral to ventral anterior surface, some of which may be quite long; thus, a total of 25 tentacles present in this specimen; chin and gut swelling prominent; ventral lip bearing several ordinary spines and a median row of peculiar flattened spines (Fig. 26*d*); dorsal lip with two high transverse ridges at base; internal surface of dorsal lip bearing a series of longitudinal and transverse grooves and ridges that are serrated; chin smooth or serrated. *Muscles:* Three main muscle masses—first including fused M I–III, second large M IV, and third, M V and x; all except V branching on each side; M IV and V joining ventral cloacal muscles; all muscles extending only a short distance laterally. For descriptions of mouth and cloacal muscles, see Metcalf (1918), Oka (1921), Sewell (1926), and Thompson (1948). *Ciliated groove:* Simple, straight, located directly under ganglion and eye. *Viscera:* Gut forming an elongate loop, in state D of Ihle and Ihle-Landenberg (1933) (Fig. 26*e*); stolon forming a loose circle around gut; endostyle extending anteriorly to base of ventral lip.

FIG. 26. *Traustedtia multitentaculata*, solitary form. *a*, Whole animal, right side, slightly from the front; *b*, schematic cross section of the test between M III and IV; *c*, body spine, 48×; *d*, ventral lip spines, 24×; *e*, gut from right side.

AGGREGATE FORM: Six specimens examined with length range of 4–13 mm. without projections (Fig. 27). The figures of Traustedt (1893), and especially Tokioka's descriptions and figures (1938), are excellent. The tentacles of this form are at most three, usually two. In addition, however, there are attachment organs that Sewell (1926) considered tentacles; this error was corrected by Thompson (1948). *Test:* Stiff, thick in all areas, especially on chin and gut swelling; mantle often far separated from test dorsally; weak dorsal elevation extending from base of cloacal flap to base of dorsal lip, limited by transverse grooves at these places; cloacal flap very large; laterodorsally, a bulging limiting elevation on each side of dorsal elevation, continuous to chin and posteriorly forming tentacle; tentacles three in young specimens: two lateral posterior, and one median posterior projecting

from end of gut projection; larger specimens without midposterior tentacle; Sewell (1926) and Tokioka (1938) figure those of the small individuals as possessing transverse constrictions, as do small POFI specimens, but the constrictions are much sparser here; tentacles flat at base, filamentous distally, with one dorsal ridge, and one ventral ridge which is continuous with posterior ridge that fuses with its fellow of the opposite side over gut; in lateral view, a broad lateral depression or narrow groove, ventral to dorsal limiting elevation, extending from base of tentacle to chin, which is smooth in POFI specimens, contrary to Sewell (1926, fig. 40) and the statement of Thompson (1948: 152); a broad ventral elevation extending from chin into gut swelling; posteriorly gut swelling forming a prominent projection bearing six large spines; four symmetrically arranged attachment organs on each side. The depressions and elevations of the test are variable. *Muscles:* Two main masses, of which the first consists of M I–II, the second of M III–IV and x; first muscle mass interrupted dorsally, second forming a distinct joint dorsally, as shown by Tokioka (1938); M IV does not help form ventral cloacal muscles, contrary to figures of Apstein (1904) and Thompson (1948); muscles extend only a short distance toward ventral surface. For a complete description of mouth and cloacal muscles, see Tokioka

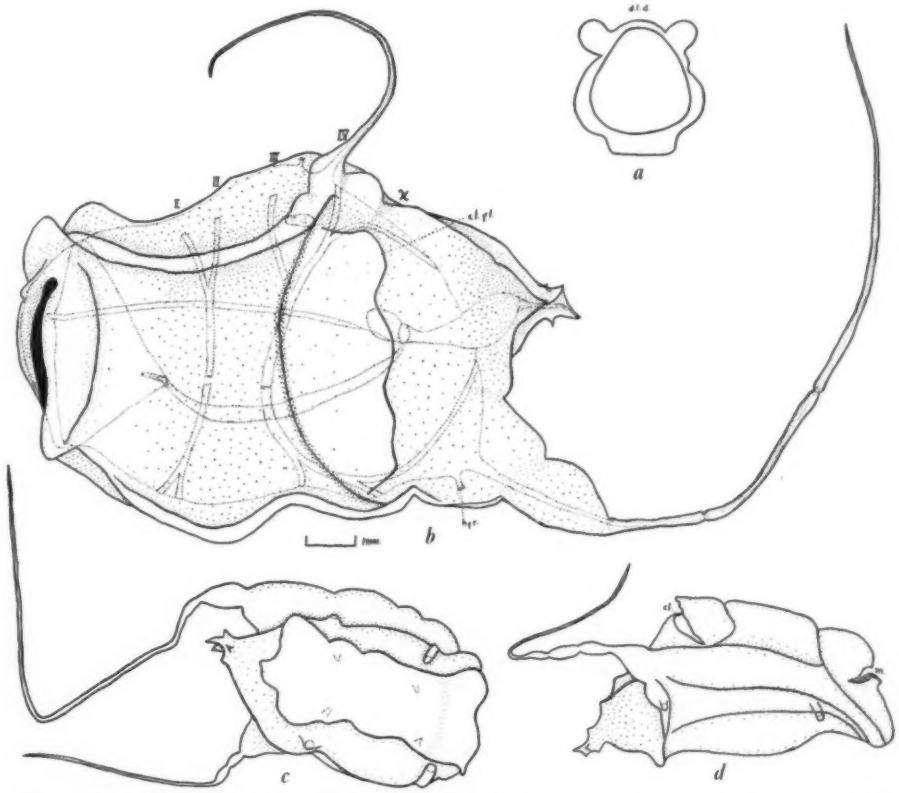

FIG. 27. *Traustedtia multitentaculata*, aggregate form. *a*, Schematic cross section of the test at level of M II; *b*, whole animal, dorsal aspect; *c*, test, ventral aspect; *d*, test, right side.

(1938). *Ciliated groove:* An open crescent; a broad languet below ciliated groove at junction with gill (Tokioka, 1938, fig. 5). *Viscera:* Gut forming elongate loop in which course of intestine is obscured by large number of testis lobules; in condition D of Ihle and Ihle-Landenberg (Tokioka, 1938); gut connected by long mantle projection with posterior gut projection; the mantle projection extending into median posterior tentacle, if present, as shown by Tokioka (1938); endostyle weakly sinuous; embryos two, lateral to joint of M III–IV on right side.

All the solitary forms described by Metcalf (1918) are probably one species, as Sewell (1926) believed. Oka (1921), however, recognized two species, *Salpa* (*Traustedtia*) *multitentaculata* and *S.* (*T.*) *henseni*, the latter being Metcalf's *S.* (*T.*) *radiata*, on the basis of the presence of eight tentacles in the former (according to my classification, 13, as he did not include in his count two paired and one unpaired pointed processes which are essentially similar to tentacles) and 20–23 in the latter. The conclusion that there is only one species is supported by the great variation in number of tentacles (varying from 7 to 25 in POFI specimens) and the probability that the radiate forms described by Apstein (1906*a*) and Dober (1912) simply were flattened dorsoventrally, giving the impression of a radiate form; this probably also explains the horizontal position of the gut of these specimens, as Sewell (1926) remarked. Sewell stated that differences in details of musculature are often due to conditions of preservation, which perhaps is the cause of differences described by Metcalf (1918). Both Oka (1921) and Sewell (1926) considered Metcalf's subspecies *bicristata* to be invalid. In POFI specimens the crested condition is one of intergradation, but crests are always present, apparently due to age differences. In one small (2 mm.) individual the crests are very small; they become more pronounced in larger individuals.

The only basis for considering the various forms distinct, according to Oka (1921) and Sewell (1926), is the different number of tentacles. Sewell (1926) distinguished between "true tentacles" and projections that penetrate the test but do not extend beyond the body margin. This, however, is probably only a condition of age and is not considered a useful distinction except for descriptive purposes. Oka (1921) remarked on the probable similarity of his "tentakeln" and "kurze . . . Anhänge" which projected from each sidewall of the cloacal opening. He also referred to "verborgene Tentakel" (those projecting into the crests and the unpaired posterior one). He did not describe any other projections. In the largest POFI specimen (Fig. 25*a*) all projections are of the true tentacle type, although many project only slightly beyond the test margin. In Sewell's (1926) and Thompson's (1948) specimens, there were nine tentacles present, including those not projecting beyond the body margin; in Apstein's (1894*b*) specimen there were eight, but, as Sewell (1926) remarked, there possibly were 13; in Metcalf's (1918) specimen and in Oka's (1921), 13 tentacles; and in Apstein's (1906*a*) and Dober's (1912) specimens, there were 20 and 23 tentacles present. Sewell (1926) thought there was a possibility that the differences were due to either geographic variation or variation in size. POFI specimens seem to confirm the latter conclusion as the number of tentacles is less with the smaller individuals and greater with larger ones. The smallest (2 mm.) specimen examined bore *no* "true tentacles" but bore seven mantle projections: one unpaired posterior; one pair of posterolateral projections (the "posterior tentacles" of Sewell and Oka and tentacle 6 of Metcalf); one pair of projections in the cloacal siphon (5 of Metcalf); one pair in the posterior part of the crests (4 of Metcalf).

Further, in a specimen of 7 millimeters length, the projections are still not "true tentacles." This specimen is so poorly preserved, however, that I am unable to ascertain the number of projections present.

In another specimen, 11 millimeters long,

the same relationships exist as in the 2-millimeter specimen described above, except the posterolateral projections (6 of Metcalf) are true tentacles and of the same length as the body.

In the largest specimen examined (16 mm.) there are 25 tentacles, as described above.

Thus, it is my belief that the tentacles also do not show variations that would lead to the separation of any of Metcalf's forms from the main species. It would be desirable to re-examine some of the larger specimens (for example, Oka's specimen of 23 mm. length), described as possessing 13 or fewer tentacles, with the use of toluidin blue. If these large specimens actually possess only 13 or less tentacles, then *T. henseni* should probably be recognized also, as Oka (1921) has done.

All aggregate forms described to the present time have been regarded as only one species, *T. multitentaculata*, and all POFI specimens agree with this conclusion.

Genus THALIA Blumenbach, 1810

Solitary form with five body muscles of which the first four form rings; aggregate form with five ventrally interrupted body muscles, with a short endostyle. Languet present in both forms ventral to the ciliated groove.

Two species, *Thalia democratica* (type) and *T. longicauda*. The latter species has not been found in the collections studied.

Thalia democratica (Forskål) 1775

Figs. 28*a–e*, 29*a–f*

Salpa democratica Forskål, 1775: 113; Bomford, 1913: 244.
Salpa mucronata Forskål, 1775: 114.
Biphora democratica Bruguière, 1789: 180.
Biphora mucronata Bruguière, 1789: 181.
Salpa cyanogaster [?] Péron and Lesueur, 1807: fig. 3.
Thalia lingulata Blumenbach, 1810: (30).
Salpa spinosa Otto, 1823: 303.

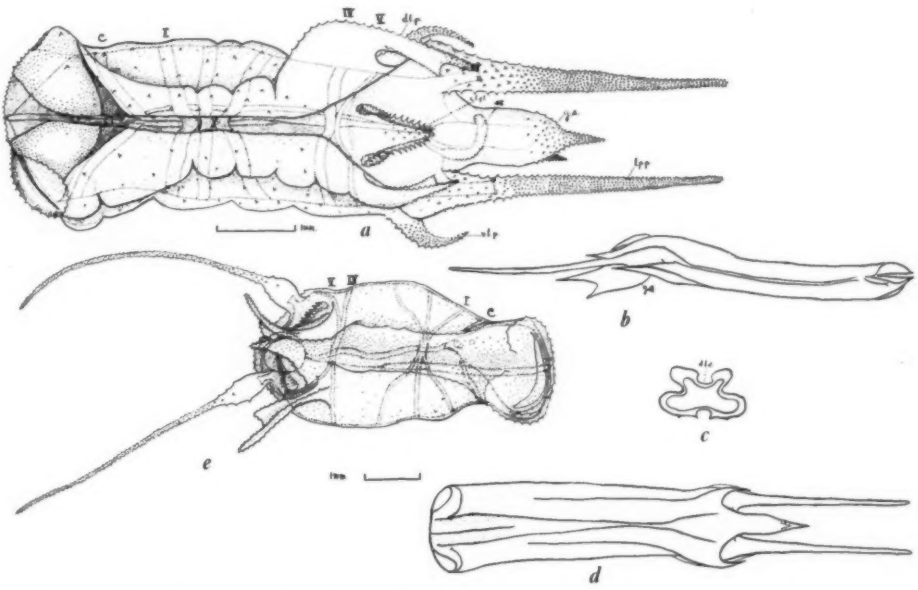

FIG. 28. *Thalia democratica*, solitary form. *a*, Echinate form, dorsal aspect; *b*, another specimen, test, right side; *c*, same specimen as *b*, schematic cross section of test at level of M III; *d*, same specimen, test, ventral surface; *e*, nonspiny form, dorsal aspect.

Salpa rhomboides [?] Quoy and Gaimard, 1824: 510.
Salpa rhomboidea [?] Blainville, 1827: 115.
Dubreuillia cirrhosa Lesson, 1830: 278.
Salpa pyramidalis [?] Quoy and Gaimard, 1834: 593.
Salpa caboti Desor, 1848: 75.
Salpa democratica-mucronata Traustedt, 1885: 365.
Thalia mucronata Lahille, 1890: 11.
Salpa (*Thalia*) *democratica-mucronata* Apstein, 1894*a:* 44.
Thalia democratica Heider, 1895: 368; Ihle, 1935: 527–529; Thompson, 1948: 139.
Salpa (*Salpa*) *mucronata* Streiff, 1908: 38.
Salpa (*Thalia*) *democratica* Metcalf, 1918: 109; Sewell, 1926: 92; Stiasny, 1926: 441; Berrill, 1950: 291.
Thalia democratica var. *orientalis* Tokioka, 1937: 226.
Thalia democratica var. *orientalis* forma *echinata* Tokioka, 1937: 229.

SOLITARY FORM: More than 10 specimens examined with length range of 4–9 mm., without projections (Fig. 28). *Test:* The echinate form (Fig. 28*a*) is discussed first. Test thick, especially over gut; gut swelling bearing two projections, one posterior and one ventroposterior; one usually long, lateral posterior projection on each side of body having no ridges but bearing many minute spines; one dorsolateral projection on either side of cloacal flap (atrial palp of Tokioka, 1937), ridged, bearing minute spines; each dorsolateral projection bearing a truncate medial portion extending posteriorly; one ventrolateral projection, usually smaller than the dorsolateral projection, extending posteriorly on each side of gut region; each a simple projection bearing minute spines; latter may be lacking, as Tokioka (1937) reported; thus, a total of six posterior projections of body and two of gut swelling; anteriorly, test truncate, ringed by an echinate ridge, with anteriorly projecting lip flaps; transverse dorsal groove at base of dorsal lip lying posterior to two bulges, one on each side of dorsal depression; dorsal depression widening anteriorly and posteriorly, limited by dorsolateral limiting elevations that continue posteriorly into lateral ridges of dorsolateral projections; in posterior widening of dorsal depression, high triangular cloacal flap projecting posteriorly, bearing a dorsal echinated ridge on its margin, a ventral heavily fringed margin below; ventral lip of cloacal opening similarly fringed, margined by a deep transverse groove; a deep lateral depression (seldom, a groove) present; a ventrolateral elevation, continuous with ventrolateral projections, coursing anteriorly; ventral surface bearing a midventral depression limited by midventral limiting ridges originating at ventrolateral projections; a prominent short midventral ridge present beneath chin. The smooth form is much like the above, having the same projections on the posterior end (often the ventrolateral projections are absent as in Fig. 28*e*), same cloacal flap structure, and the anterior ridge around the mouth; dorsal depression and limiting ridges present (these may be only elevations). The test, however, is not spiniferous ventrally and is sparsely so dorsally; it is thin and flabby. The muscles of this form are narrower than those of the echinate form. *Muscles:* One large bow muscle (C) interrupted dorsally, continuous ventrally; five body muscles present; M I–IV continuous dorsally and ventrally; M V continuous dorsally, narrowly interrupted ventrally (Metcalf, 1918, says M V is continuous ventrally, but all other investigators described it as interrupted, as here); M I–III converge in midline dorsally as do M IV and V, thus forming two dorsal groups; M III and IV converge, usually touch midventrally. *Ciliated groove:* Far separated from ganglion and eye, bearing a languet projecting ventrally into the pharyngeal cavity. *Viscera:* Gut elongate and U-shaped, in state B (Ihle and Ihle-Landenberg, 1933); projecting far into gut swelling; endostyle extending only from level of M III forward; stolon forming a close circle or spiral around gut.

AGGREGATE FORM: More than 10 specimens examined with length range of 1–12 mm. (Fig. 29). *Test:* The echinate form (Fig. 29*a*) is discussed first. Test asymmetric, thick, stiff, with prominent, sparsely spiniferous ridges and with deep grooves and depressions; middorsal depression (limited to anterior region in some specimens) limited by spiniferous dorsal limiting ridges; depression constricted at base of dorsal lip, widening anteriorly around mouth; a transverse ridge in front of cloacal flap; cloacal flap hemispherical rather than triangular, fringed as in solitary form; gut swelling projecting in a point toward rear (this may be very long in young specimens as figured by Apstein, 1906*a*, Sewell, 1926, and Tokioka, 1937), bearing five spiniferous ridges that are usually symmetrically arranged; lateral ridges asymmetric, spiniferous; anterior end almost truncate; ventrally a single deep groove in a broad depression cut off anterolaterally by an oblique spiniferous ridge that connects with anterior end; gut swelling with a strong ventral ridge; attachment organs varying in number, elongate and filiform (but usually not projecting beyond test margin). There is a great amount of test variation as reported by Stiasny (1926). In the smooth form (Fig. 29*e*), test flabby, without spines of any kind, with long attachment organs usually projecting beyond test outline; no permanent ridges or grooves, but there may be depressions and elevations; protruding gut swelling; cloacal flap with fringes. *Muscles:* Five body muscles; M V relatively narrow; all muscles continuous dorsally, interrupted ventrally; M I–III in contact dorsally, forming a group as do IV and V. *Ciliated groove:* Far anterior; simple, with a languet projecting into pharynx. *Viscera:* Gut compact, in condition B (Ihle and Ihle-Landenberg, 1933); elongate; protruding far into gut swelling; endostyle short, extending anterior to level of M I or II only; embryo far behind M IV on right ventral body wall.

The variety *orientalis* recognized by Tokioka (1937) is based on the following differences:

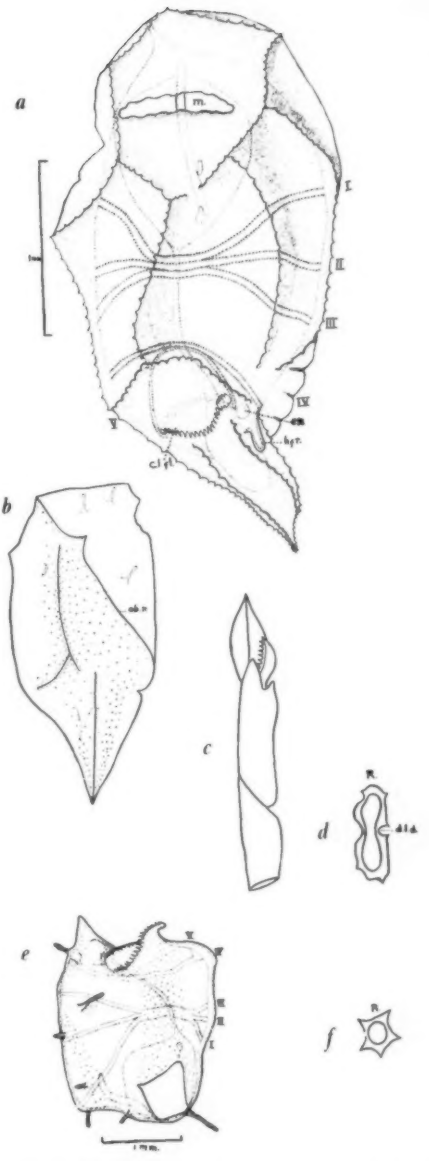

FIG. 29. *Thalia democratica*, aggregate form. *a*, Echinate form, dorsal surface; *b*, same specimen, test, ventral surface; *c*, same specimen, test, right side; *d*, same specimen, schematic cross section of test at level of M III; *e*, smooth form, right side, slightly dorsal; *f*, scheme of cross section of test at gut swelling of specimen in *a*.

small size; atrial palp bifurcated; smooth appearance of the testis lobes. Moreover, he distinguished the form *echinata* on the basis of "the existence of several spiniferous ridges on the testa." Sewell (1926) also distinguished a spiniferous form and found them to be uniformly of a smaller size than Atlantic specimens. In the POFI collections there are also two forms distinguishable on the basis of test differences, the one an echinate form, the other a smooth form; both are small. There are, however, among solitary individuals, intergrading degrees of echination, but conclusions on the validity of Tokioka's variety and form deserve further study, especially of a series of specimens from different oceans.

Although this species is the most common salp of warm seas (Apstein, 1906*a*), it is not one of the better known in regard to test structure. Apstein (1906*a*) figured the echinate aggregate form well, as did Stiasny (1919) and Tokioka (1937). The smooth form of both generations was well figured by Stiasny (1926). It is felt, however, that the figures in the present report are more thorough than previous ones as a result of staining.

Genus Iasis Savigny, 1816

Solitary form with five broad, dorsally and ventrally interrupted body muscles and with a broad M C. Aggregate form with five body muscles of which the first is interrupted dorsally and ventrally, the remainder only ventrally; M V is branched into two parts on the right side.

One species, *Iasis zonaria*.

Iasis zonaria (Pallas) 1774
Fig. 30*a–i*

Holothurium zonarium Pallas, 1774: 26.
Salpa polycratica Forskål, 1775: 116.
Biphora zonaria Bruguière, 1789: 182.
Salpa zonaria Chamisso, 1819: 12; Bomford, 1913: 245.
Salpa cordiformis Quoy and Gaimard, 1827: 226.
Salpa microstoma Quoy and Gaimard, 1827: 226.
Salpa unicuspidata Blainville, 1827: 116.
Salpa quadrangularis [?] Lesson, 1830: 268.
Salpa tricuspidata [?] Lesson, 1830: 272.
Salpa cordiformis-quadratica Vogt, 1854: 7.
Salpa cordiformis-zonaria Traustedt, 1885: 382; Oka, 1915: 30.
Salpa nitida [?] Herdman, 1888: 81.
Jasis polycratica Lahille, 1890: 11.
Salpa (*Jasis*) *cordiformis-zonaria* Apstein, 1894*a:* 51.
Jasis zonaria Heider, 1895: 368.
Salpa zonaria-cordiformis Ritter, 1905: 76.
Salpa (*Salpa*) *zonaria* Streiff, 1908: 45.
Salpa (*Iasis*) *zonaria* Metcalf, 1918: 100; Stiasny, 1926: 434; Berrill, 1950: 295.
Salpa (*Jasis*) *zonaria* Sewell, 1926: 88.
Iasis zonaria Ihle, 1935: 527–529; Tokioka, 1937: 223; Thompson, 1948: 132.

SOLITARY FORM: More than 10 specimens examined with length range of 16–51 mm. (Fig. 30*a–e*). *Test:* Firm, elongate; moderately thick; mouth a broad slit; dorsal depression extending to base of upper lip, limited by dorsal limiting elevations; a lateral ridge on each side of latter gradually disappearing anteriorly; posteriorly, lateral ridges ascending to pointed, short, dorsal projections; a posterior ridge extending from the latter ventrally, fusing with its fellow of the opposite side midventrally at the longer, unpaired, median posterior projection; projections prominent in lateral view; a deep lateral groove, or a wide depression as shown by Brooks and Stiasny, gradually forming ventral and anterior to dorsal posterior projections, continuing anteriorly to the front third of body; a ventrolateral ridge extending from gut swelling, coursing anteriorly up to ventral lip; gut swelling moderately large; midventral ridge on posterior region of gut swelling; midventral depression coursing anteriorly from this to base of lower lip; this depression raised slightly in cross section, limited on each side by deep grooves; ventrolateral elevation bearing a ventrolateral ridge (which may be weak)

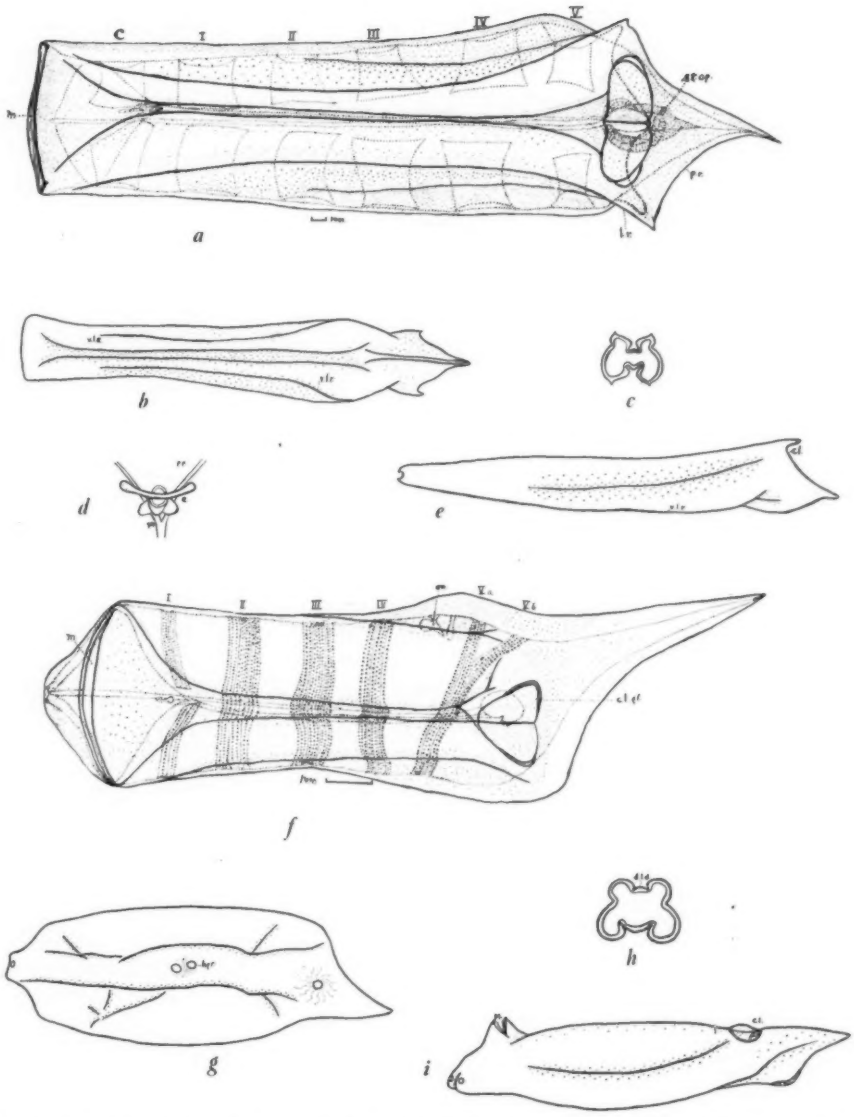

FIG. 30. *Iasis zonaria*. *a*, Solitary form, dorsal aspect; *b*, same specimen, ventral surface of test; *c*, same specimen, schematic cross section of test at level of M III; *d*, another specimen, dorsal aspect of eye and ganglion; *e*, same specimen as *a*, test, left side; *f*, aggregate form, dorsal aspect; *g*, another specimen, test, ventral surface: *h*, schematic cross section of test at level of M IV; *i*, same specimen as *g*, test, left side.

swinging outward at level of gut swelling and inward toward anterior third of body; cloacal flap of two fused halves, fringed as in *Thalia democratica;* transverse groove anteriorly at base of flap, posteriorly around cloacal opening. *Muscles:* M C and the five body muscles are broad; all muscles interrupted dorsally and ventrally; M V relatively narrow, extending only a short distance toward ventral surface. *Ciliated groove, ganglion and eye:* Ciliated groove simple, straight, located between the two bow muscles; ganglion and eye between M C and M I; eye may be transversely elongate (Fig. 30*d*). *Viscera:* Gut in condition D of Ihle and Ihle-Landenberg (1933); stolon forming circle around gut, opening to outside of test by means of a posterior opening just above gut (small in Fig. 30*a* but may be much larger).

AGGREGATE FORM: More than 10 specimens examined with length range of 19–37 mm. (Fig. 30*f–i*). *Test:* Asymmetric; consistency as in solitary form; dorsal depression (raised in cross section) with deep groove on each side but without fine median ridge described by Stiasny (1926), extending to base of upper lip; dorsal limiting elevations may bear a weak ridge on each side of depression; anteriorly both lips project dorsally prominently; a prominent chin forming anterior to lower lip; laterally a deep lateral groove (often a broad depression) extending from region of cloacal flap to level of mouth (weak ridges may course above and below this); lips and chin prominent in lateral view; ventrolateral elevation extending posteriorly as a ridge onto posterior projection; gut swelling prominent; on ventral surface, a broad, raised in cross section, midventral depression with a deep groove on each side, extending to chin; limited by ventrolateral elevations; rear projection always on right side, usually long but may be short; a broad, long mantle process extending into posterior projection; attachment organs prominent; two anteriorly directed, one ventrally directed on chin; two midventral, raised on an elevation; three posterior, raised on an elevation of gut swelling. The number described is the maximum number as reported by Streiff (1908) and Stiasny (1926). Some individuals may deviate from this maximum (Fig. 30*g*). Further, Stiasny shows two prominent lateral ridges rather than a single lateral groove. He also shows prominent dorsal ridges ("Crista") which are usually only rounded elevations on the specimens examined here, but in general his description is applicable. *Muscles:* Five body muscles (M C is not shown in figure); all interrupted ventrally, M I interrupted dorsally as well; M V dividing into two branches on right side, remaining single on left. *Ciliated groove:* Simple, anterior to M I. *Viscera:* Gut compact, in condition F of Ihle and Ihle-Landenberg (1933); testis projecting as lobules around gut; up to five embryos present dorsally on right between M IV and V.

This species is morphologically one of the best-known salps as its test has a different refractive index than water, even though it is transparent. The test has been figured well by Brooks (1893) and Stiasny (1926) and described in detail by Stiasny.

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Some Polyclad Flatworms from the Hawaiian Islands

LIBBIE H. HYMAN[1]

ONE MAY SUPPOSE that a rich polyclad fauna exists along the shores of the Hawaiian Islands, but our knowledge of Hawaiian polyclads is, in fact, very limited. As far as I can ascertain, only the following species are recorded from the Hawaiian Islands in the literature: *Planocera hawaiiensis* Heath, 1907; *Taenioplana teredini* Hyman, 1944; and *Stylochoplana inquilina* Hyman, 1950. The first merits further examination, but the specimens cannot be located. Three further species from Hawaii have been received for identification, from the United States National Museum, and furnish the material for the present article, which thus adds something to our small knowledge of the polyclad fauna of these islands. All three species belong to the Acotylea and to the section Schematommata. As the taxonomic categories that concern these three species have been carefully defined in a recent publication (Hyman, 1953*a*), there appears no need for repetition of these definitions here.

Family *LEPTOPLANIDAE*

Euplana tropicalis n. sp.
Fig. 1

The species is based on one specimen that was collected near Kapoho, Hawaii, September 25, 1929. The species is rather large, of elongated oval form, 38 millimeters long by 17 millimeters wide (Fig. 1*a*), but, as it is evidently contracted, it presumably reaches a much greater length. The specimen had acquired the usual dark-brown color typical of museum specimens but in life was probably tan with dark-brown spots. The tentacular eyes form small but conspicuous clusters of about 10 eyes on one side and 15 on the other, but the cerebral eyes could not be made out satisfactorily. They appeared to be very few in number and were seen chiefly on one side. The form of the pharynx as far as seen and the locations of mouth and gonopores appear in Figure 1*a*.

The posterior half was removed and the region of the copulatory complexes sectioned sagittally. The histological condition is poor, but the parts of the complexes were followed satisfactorily and are represented in schematic sagittal view in Figure 1*b*. Both complexes appear unusually sinuous, much more so than as represented in the figure, but whether this is natural or the result of the contraction of the specimen is uncertain. The complexes occur shortly behind the pharynx as is usual in the Leptoplanidae. The gonopores are widely separated. The male gonopore leads into a somewhat expanded male antrum lined with a sinuous epithelium and bearing at its inner end a small penis sheath. From this a long penis pocket proceeds anteriorly, sur-

[1] American Museum of Natural History. Manuscript received June 19, 1953.

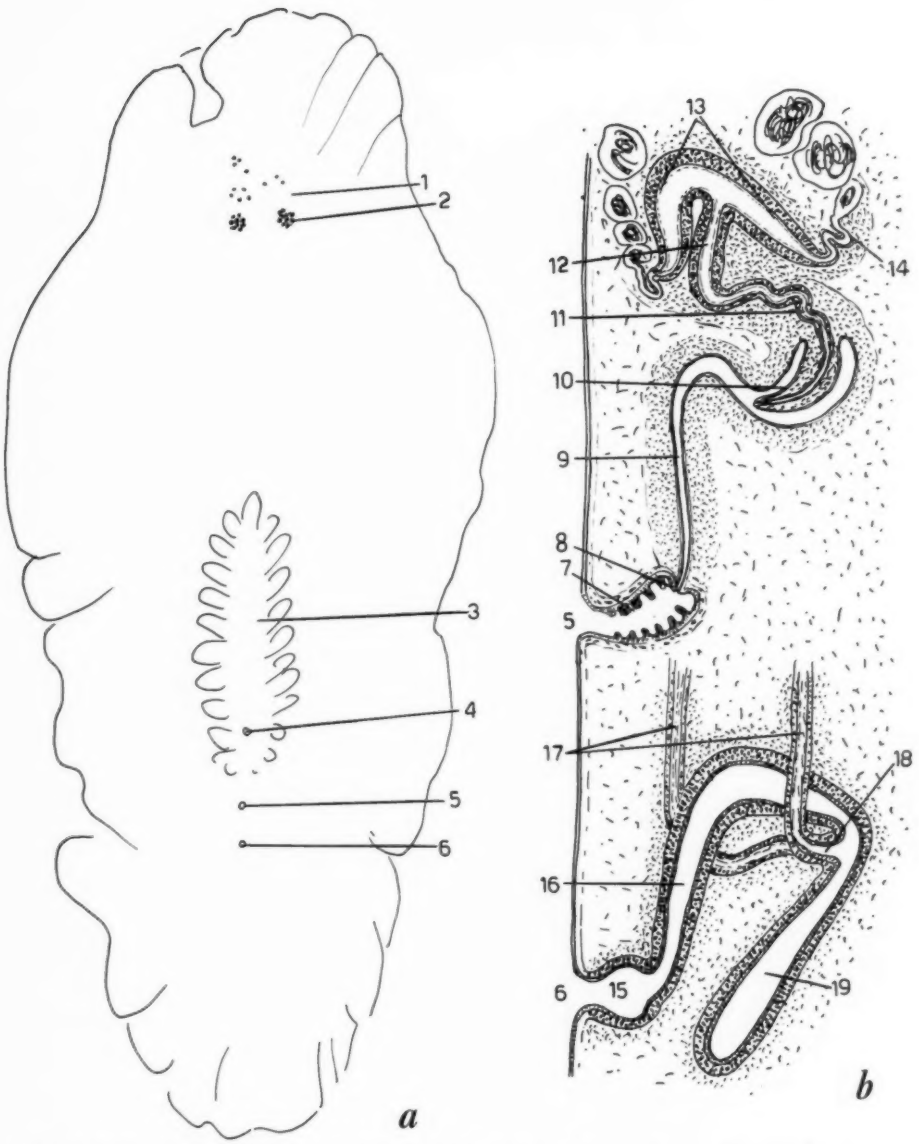

FIG. 1. *Euplana tropicalis*. *a*, Entire specimen; *b*, sagittal view of the copulatory complexes from sections. 1, Cerebral eyes; 2, tentacular eyes; 3, pharynx; 4, mouth; 5, male gonopore; 6, female gonopore; 7, male antrum; 8, penis sheath; 9, penis pocket; 10, penis papilla; 11, ejaculatory duct; 12, seminal vesicle; 13, horns of seminal vesicle or spermiducal bulbs; 14, sperm duct; 15, female antrum; 16, vagina; 17, uteri; 18, entrance of oviduct into vagina; 19, Lang's vesicle.

rounded by dense mesenchyme, and after bending dorsally terminates in a slightly expanded chamber housing the elongated, conical penis papilla. The central duct of the papilla, or ejaculatory duct, proceeds forward and downward very sinuously and becomes continuous with the central part of a tripartite seminal vesicle. This has pronounced muscular walls of chiefly circular fibers. It is very peculiar in that one horn of this tripartite structure descends ventrally, receiving one sperm duct, and the other ascends dorsally, receiving the other sperm duct. This lack of bilateral symmetry in the entry of the sperm ducts into the seminal vesicle is certainly very unusual. Possibly the two horns of the tripartite seminal vesicle should be regarded as spermiducal bulbs, that is, as thickened terminations of the sperm ducts.

The female gonopore leads into a short, expanded antrum from which the vagina proceeds forward and then dorsally in a very sinuous manner, not indicated in the figure. Shortly after bending from a vertical to a horizontal position, the vagina receives the common oviduct and then continues as an oval Lang's vesicle. The female tract throughout has a well-developed muscular coat of mainly circular fibers. The same peculiar asymmetry seen in the entry of the sperm ducts into the male apparatus also obtains in the entry of the oviducts into the vagina. As shown in Figure 1*b*, one oviduct is situated ventrally, the other dorsally. Cement glands were not evident, no doubt because of the poor histological condition. The uteri also could not be traced anteriorly.

A penis papilla at the inner end of a long male antrum guarded distally by a penis sheath also characterizes two other species of *Euplana—concolor* Meixner, 1907, and *clippertoni* Hyman, 1939. However, a penis stylet is present in the latter, and the Lang's vesicle is very small in the former. Further, no other species of *Euplana* has the peculiar asymmetry of the sperm ducts and the oviducts that distinguishes *E. tropicalis*.

The holotype has been deposited in the United States National Museum in the form of slides bearing the anterior half mounted whole and the copulatory complexes as sagittal serial sections.

Family *PLANOCERIDAE*

Paraplanocera oligoglena
(Schmarda) 1859

One specimen of this species, collected by H. W. Henshaw at Hilo, Hawaii (no date), was sent as a whole mount. The specimen was much ruffled, measuring 33 millimeters in length by 28 millimeters in breadth. The features of the copulatory apparatuses, including the two large teeth at right angles to each other in the cirrus sac, were readily seen in the whole mount and considered to establish the identification without the necessity of sections. This species is cosmopolitan in tropical and subtropical waters and has been recorded from a number of localities in the Indo-Pacific region, further from the Gulf of California (Hyman, 1953*a:* 353–357). The whole mount has been returned to the U. S. National Museum.

Planocera pacifica n. sp.
Figs. 2, 3

A fine, perfect specimen was taken in the Hawaiian Islands by P. S. Galtsoff, July 27, 1930, in the evening, hence presumably swimming at the surface. The specimen (Fig. 2) is of broadly oval form, with ruffled margins, 40 millimeters long by 25 millimeters wide. The color is indeterminable, but the worm appears thin and transparent. There is a pair of conspicuous conical tentacles near the brain, far back from the anterior margin. A ring of tentacular eyes occurs at the base of each tentacle. The fairly numerous, small cerebral eyes (Fig. 3*a*) are more abundant anterior to than behind the brain level. The broad, ruffled pharynx with about six main lateral folds on each side occupies approximately the central region of the worm (Fig. 2), and di-

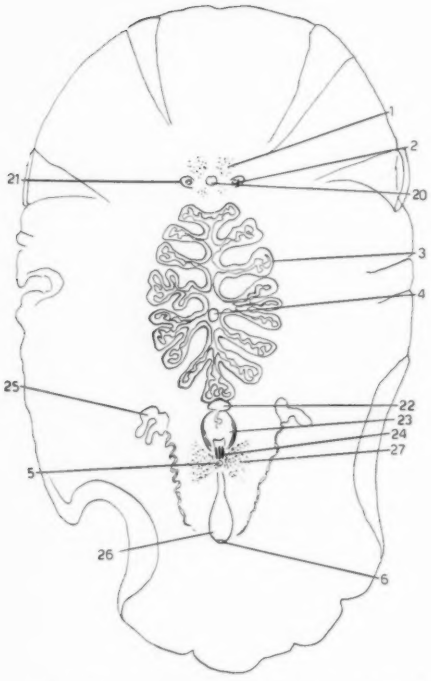

FIG. 2. *Planocera pacifica*, entire specimen. 1, Cerebral eyes; 2, tentacular eyes; 3, pharynx; 4, mouth; 5, male gonopore; 6, female gonopore; 20, brain; 21, tentacles; 22, prostatic vesicle; 23, cirrus sac; 24, large teeth of cirrus sac; 25, uterine sac; 26, bulbous antrum; 27, cement glands.

rectly behind it is seen the male copulatory apparatus, armed near the male gonopore with three large teeth. Behind this is seen the bulbous termination of the female copulatory apparatus. To either side of the male apparatus there occurs a sacciform enlargement of the uterus, presumably for the purpose of storing eggs. Such sacs are unusual in acotylean polyclads. The details of the copulatory apparatuses, insofar as they could be seen in the cleared whole specimen, are shown in Figure 3*b*.

For species discrimination, it was considered necessary to remove the copulatory region of the worm and section it sagittally. A view of the copulatory complexes as constructed from the series of sagittal sections is given in Figure 3*c*. At the anterior end of the male apparatus is seen the elongated, curved seminal vesicle closely applied to the ventral wall of the prostatic vesicle. The common sperm duct enters the ventral surface of the seminal vesicle, passes slantingly and upward in the muscular wall of this vesicle, then turns back and becomes the lumen of the vesicle. It enters the proximal end of the cirrus sac in contact with the prostatic duct. The prostatic vesicle is a slightly oval sac situated at the anterior end of the cirrus sac but not bound with the latter in its muscular sheath. The prostatic vesicle has a thin muscular wall, and the interior is filled as usual with a much-folded, glandular eosinophilous lining. The short prostatic duct and the duct of the seminal vesicle enter the anterior end of the cirrus sac in contact with each other and terminate in the beginning of the ejaculatory duct. The cirrus sac is a large oval body with a thick muscular wall distally, a thinner wall proximally. This proximal half of the cirrus sac is filled with a loose tissue traversed by diagonal muscle fibers and contains the slightly sinuous ejaculatory duct. This opens on a projection into what is presumably the lumen of the cirrus sac. This is widened anteriorly around the projection in question, then narrows to a tube running to the male gonopore. The lumen of the cirrus sac is lined by small teeth that increase in size distally. At the distal end of the cirrus lumen, where it opens into the male gonopore, are the three large teeth already mentioned. One of these and part of another appear in Figure 3*c*.

The female gonopore occurs some distance behind the male pore and leads into an antrum with excessively thick muscular walls, composed of circular and radiating fibers intermingled. This muscular antrum, or bulbous vagina as it is termed by some, extends anteriorly, gradually narrowing until it reaches nearly the level of the male gonopore. It then narrows abruptly into the vagina which turns first backward and then forward again, run-

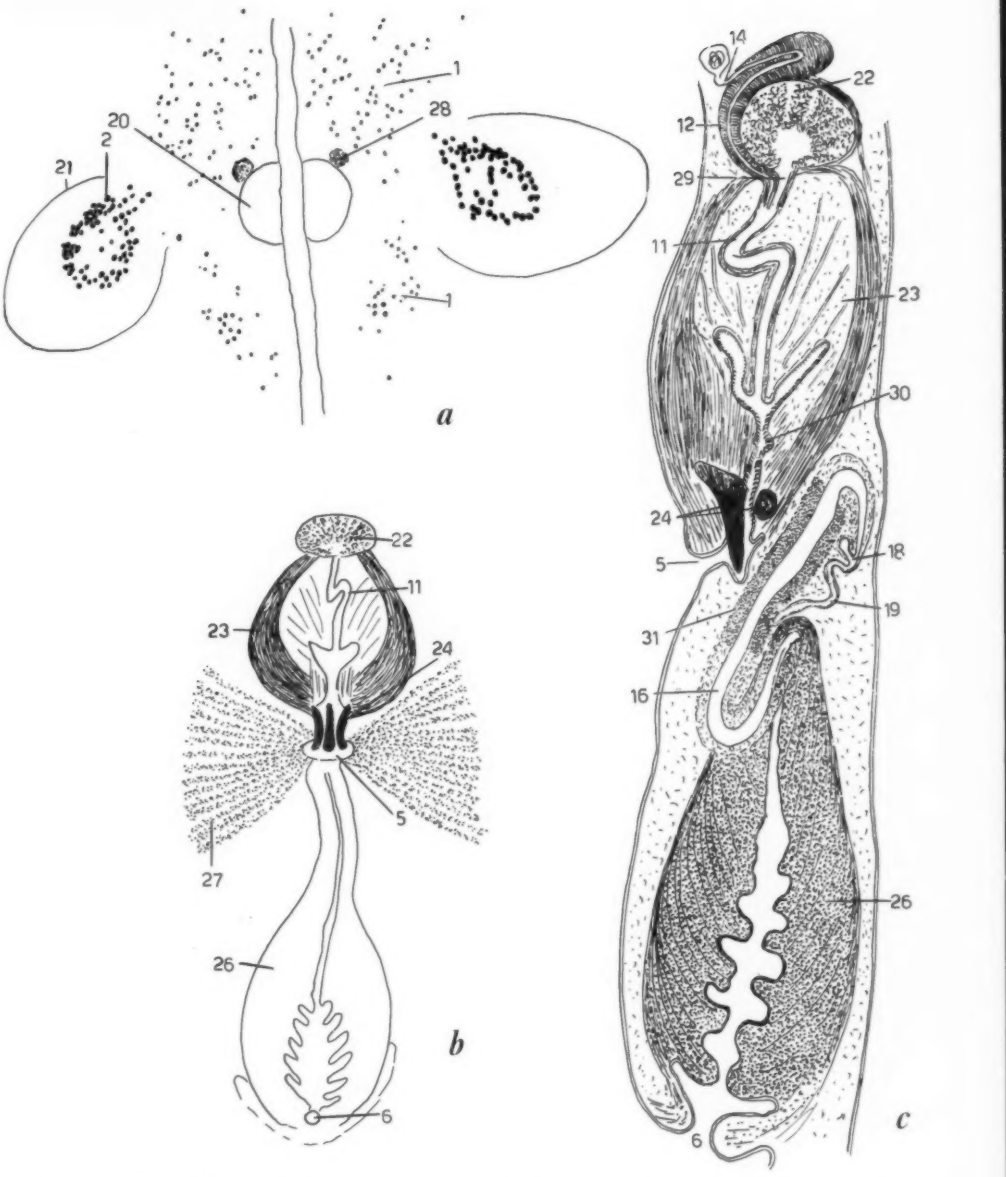

FIG. 3. *Planocera pacifica*. *a*, Enlarged view of eyes and tentacles; *b*, copulatory complexes seen from above in cleared entire specimen; *c*, sagittal view of the copulatory complexes from sections. 1, Cerebral eyes; 2, tentacular eyes; 5, male gonopore; 6, female gonopore; 11, ejaculatory duct; 12, seminal vesicle; 14, sperm duct; 16, vagina; 18, entrance of oviduct into vagina; 19, Lang's vesicle; 20, brain; 21, tentacles; 22, prostatic vesicle; 23, cirrus sac; 24, large teeth of cirrus sac; 26, bulbous antrum; 27, cement glands; 28, granule masses of brain; 29, prostatic duct; 30, small teeth lining lumen of cirrus sac; 31, cement glands entering vagina.

ning just above the distal part of the cirrus sac. Along much of this course it is heavily supplied with cement glands. It then turns backward, narrowing as it receives the common oviduct; beyond this it continues for a short distance as a narrow, tubular, somewhat sinuous Lang's vesicle.

Until recently but one species of *Planocera* with three large teeth in the distal end of the cirrus sac was known, namely, *P. crosslandi* Laidlaw (1903: 100), from the coast of British East Africa. Laidlaw gave a good description of this but did not furnish any figures. Recently Prudhoe (1952: 175) assigned a specimen from the Gulf of Aqaba, Red Sea, to *P. crosslandi* on the basis of the presence of three large cirrus spines but did not section the worm. I recently studied a *Planocera* from the Galápagos Islands with three large teeth in the distal end of the cirrus sac and decided it was not identical with *P. crosslandi*, naming it *tridentata* (Hyman, 1953*b*: 188). Both *tridentata* and *pacifica* differ from *crosslandi* in that the prostatic vesicle is not bound in common with the cirrus sac in the same muscular sheath. Further, *tridentata* lacks a Lang's vesicle, having instead a very long and narrow vagina recurved on itself, whereas *crosslandi* is described as having a long, thread-like Lang's vesicle, and in *pacifica* Lang's vesicle is short and tubular. It may be concluded that there are several species of *Planocera* armed with three large teeth at the exit of the cirrus sac and that the presence of these teeth is not a sufficient basis for species identification.

The holotype, preserved in alcohol, has been deposited in the U. S. National Museum, accompanied by the slides of sections of the removed copulatory region.

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Occurrence of Sponges in an Aquarium

M. W. de Laubenfels[1]

On October 6, 1947, nine species of sponge were found growing in one of the tanks of the Honolulu Aquarium. Two of these prove to be as yet undescribed.

According to information furnished by Mr. Spencer Tinker, the director of the aquarium, none of these sponges were brought to the tank as adults. Most or all of them must have reached it as larvae in the running sea-water circulation. Some may have come as minute juveniles attached to marine objects which were placed in the aquarium.

It is curious to note that this astonishing abundance of sponges occurred in only one of the many tanks of the aquarium. It appeared desirable to make a continuing study of this phenomenon, and instructions were left for careful preservation of it, but a few days later an attendant meticulously destroyed every bit of this sponge population.

Study of sponges in the tanks of the Honolulu Aquarium was then continued for 3 years. For 12 months of the year, with some seasonal fluctuation in size, one might find a few small *Tethya* and an occasional encrusting sponge in the many tanks, but the sponges were consistently too small and juvenile for identification.

This latter situation is in harmony with the usual extreme scarcity of "volunteer" sponges in aquariums.

The nine species may be described as follows:

Haliclona permollis
(Bowerbank) de Laubenfels

This species was represented by thin, translucent incrustations with lumpy or slightly conulose surface. Some were nearly colorless; one was bright violet, the typical color of this species. Many of the volunteers observed subsequent to October, 1947, may have been of this sort. It is described in Pacific Science (de Laubenfels, 1951: 258) from specimens taken elsewhere in Hawaii. It is an abundant species of world-wide distribution.

Adocia gellindra de Laubenfels

This species was described (de Laubenfels, 1932: 114) from California and not recorded again until now. It is rather close to the widespread species *Adocia cinerea* (Grant), but its spicules are smaller than those of *cinerea*. In the Honolulu Aquarium it was represented by a single pale crust on a rock; it may have been fetched from the ocean along with that rock, but the rocks so brought in were so roughly treated, often out of water entirely, that this origin is not certain. In fact, it is more probable that this species is also a volunteer.

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The Honolulu specimen showed a number of oscules, 2.5 to 4 millimeters in diameter, with raised rims. It had a distinct ectosome over extensive subdermal cavities; this dermis contained a tangent isodictyal reticulation. The spicules were all oxeas, about 5 by 140 microns in dimensions.

Toxadocia violacea de Laubenfels

This species was described (de Laubenfels, 1950: 16) as occurring on the shores of Oahu. It has since been found on other Pacific islands, and there is an unpublished instance of its occurrence interidally on the coast of California. In the Honolulu Aquarium it was represented by several small specimens on the concrete walls, each with an oscule surrounded by a rim so high that a tubular structure resulted, 2 millimeters in diameter, 3 to 5 millimeters high. The oxeas were 5 by 105 microns, the toxas 60 microns long. The flagellate chambers were especially large, commonly 50 to 60 microns in diameter.

Timea xena n. sp.

The holotype of this species is designated as a spirit-preserved specimen, U. S. National Museum register number 23505. It was a thin orange crust on one of the concrete walls of the aquarium, only 550 microns thick. As is usual in such thin specimens, oscules and pores were not evident. The smooth ectosome was 15 to 30 microns thick, darker than the endosome, and was packed with microscleres. In the endosome fascicular tracts of megascleres occurred, points toward the surface, tract diameter 20 to 25 microns. These columns were perpendicular to the substrate and were 100 to 150 microns apart.

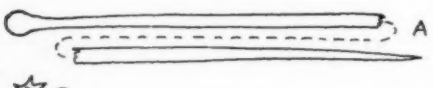

FIG. 1. Spicules of *Timea xena*, camera lucida drawing. × A, Tylostyle, B, spheraster.

The skeleton includes megascleres and microscleres. The former are tylostyles 3.5 by 200 microns in dimension. The latter are asters 10 microns in diameter, probably to be classified as oxyspherasters, but with very small centrums.

There are already some eight species in *Timea*. All have megascleres much larger than those of *xena;* conceivably this might be ecologic, but there is no dependable evidence that aquarium life produces smaller spicule size. The only species hitherto recorded from the Pacific Ocean is *tetractis* Hentschel (1912: 322) from the East Indies. It is described with excessive brevity but characterized by peculiar acanthose microscleres. Only two other species of *Timea* have oxyasters, and each of them has tylasters in addition; of these two, *squamata* was black, and *parasitica* had the oxyasters 25 microns in diameter and its smaller (12 microns) asters were tylasters.

The species name selected is derived from a Greek word meaning "guest."

Kotimea tethya n. sp.

The holotype of this species is designated as a spirit-preserved specimen, U. S. National Museum register number 23504. It also was a pale orange crust on one of the concrete walls of the aquarium. Like the preceeding species, it was lipostomous. Not only did it lack cortex, but there was almost no dermal specialization of any kind. The endosome showed no trace of fascicular or radiate structure.

The megascleres were styles, 14 by 700 microns in dimensions. The microscleres were oxysphereasters with relatively large centrums, up to 38 microns in diameter, also (rare) oxyeuasters 20 microns in diameter (not illustrated), and oxyspherasters only 5 to 7 microns in diameter.

This is an interesting specimen in that its spicules are practically identical with those of the genus *Tethya*. On the other hand, all species of *Tethya* are both corticate and ra-

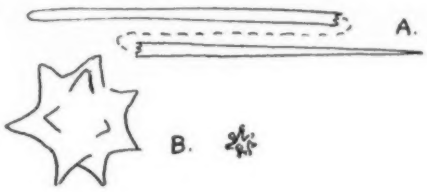

FIG. 2. Spicules of *Kotimea tethya*, camera lucida drawing. A, Style, × 180. B, spherasters, × 780.

diate. Even when juvenile, specimens of *Tethya* are globular and rough, often already showing the tuberculate surface that is so characteristic of the adults. Many sponge species have juvenile incrusting stages, but not so *Tethya*.

Lest one assume that the specimen now under discussion might be a *Tethya* profoundly modified by the artificial environment, it may be pointed out that *Tethya diploderma* is the commonest volunteer sponge in the Honolulu Aquarium, one that continued to be found throughout subsequent years. In the same aquarium with this *Kotimea* on October 6, 1947, there were numerous specimens of *Tethya*, some obviously very young, others older and larger. All were typical, with globular shape, pronounced cortex, and radiate internal structure.

There are two other species already in the genus *Kotimea*. The type is *moorei*, described as *Hymedesmia moorei* by Carter (1880: 472) from Ceylon. Its microscleres were much like those of *Tethya*. Its megascleres were about as long, but were twice as thick, and some were tylostyles. This latter difference is here regarded as significant. The other species was described as *Hymeraphia spiniglobata* by Carter (1879: 301) from the South Pacific. It had only tylostyles and only the largest sort of spheraster.

The species name selected calls attention to the resemblance to *Tethya*.

Terpios zeteki de Laubenfels

This species was first described from the Pacific coast of Panama (de Laubenfels, 1936: 450). It is abundant in Hawaii and therefore was redescribed (de Laubenfels, 1950: 28).

This species is regularly yellowish as to endosome, but its exterior is in some specimens blue, in others red. The specimen in the Honolulu Aquarium was incrusting, with the normal endosome and a crimson-red ectosome.

Tethya diploderma Schmidt

This world-wide species is common in Hawaii and, as already noted, even regularly invades the Honolulu Aquarium tanks. In the tank now under discussion there were nearly a score of specimens of *Tethya*, well distributed about the walls, bottom, and loose rocks.

This species was redescribed (de Laubenfels, 1950: 30).

Oscarella tenuis Hentschel

This species was described by Hentschel (1909: 351) from Australian waters; this is its next recorded occurrence. In the Honolulu Aquarium it was represented by a single, opaque, whitish incrustation on the concrete wall, paper-thin and about 3 centimeters in diameter. Its flagellate chambers were 30 microns in diameter.

This genus has no mineral or spongin skeleton, consisting only of the protoplasmic structures and some inanimate colloidal stuff.

It is doubtless much more abundant than the few records would seem to indicate but is ordinarily overlooked. Even when noticed, it is usually hopelessly ruined in the process of scraping it off rock or coral, so that the necessary histological study becomes impossible.

Leucosolenia eleanor Urban

This species is abundant along the west coast of the United States; this is its first record from elsewhere.

This is a calcisponge of the simplest, or Ascon, type. The Ascon tubes are long, however, with many branches and anastomoses, so that a clathrous structure results.

The sponge in the Honolulu Aquarium had pale flesh-colored Ascon tubes only about 300 microns in diameter. The spicules were principally triacts, with rays 11 by 110 microns. Tetraxons were probably present but were rare, as in other specimens of *eleanor*. The oxeas were chiefly ectosomal, 10 by 150 microns in dimension, often hastately pointed at one end.

It is of exceptional interest to observe the relationship of this aquarium fauna to that of the east shore of the Pacific. Except for the two new species, and the possible exception of the *Oscarella* (probably merely overlooked), all these species occur also on the Pacific coast of North America.

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The Taxonomic Position and the Scientific Name of the Big Tree known as *Sequoia gigantea*

HAROLD ST. JOHN and ROBERT W. KRAUSS[1]

FOR NEARLY A CENTURY it has been customary to classify the big tree as *Sequoia gigantea* Dcne., placing it in the same genus with the only other living species, *Sequoia sempervirens* (Lamb.) Endl., the redwood. Both the taxonomic placement and the nomenclature are now at issue. Buchholz (1939: 536) proposed that the big tree be considered a distinct genus, and he renamed the tree *Sequoiadendron giganteum* (Lindl.) Buchholz. This classification was not kindly received. Later, to obtain the consensus of the Californian botanists, Dayton (1943: 209–219) sent them a questionnaire, then reported on and summarized their replies. Of the 29 answering, 24 preferred the name *Sequoia gigantea*. Many of the passages quoted show that these were preferences based on old custom or sentiment, and that few of them were willing to accept whatever name proved correct under the laws of nomenclature. Only 3 of the 29, on consideration of the botanical characters of the big tree, came to the conclusion that it represented a distinct genus and should be called *Sequoiadendron;* and of the three, two were willing to accept it only provisionally. The replies to this questionnaire make an interesting psychological document, but its majority vote does not settle either the taxonomy or the nomenclature of the big tree. No more does the fact that "the National Park Service, which has almost exclusive custody of this tree, has formally adopted the name *Sequoia gigantea* for it" (Dayton, 1943: 210) settle the question.

The first issue is the generic status of the trees. Though the two species differ conspicuously in foliage and in cone structure, these differences have long been generally considered of specific and not of generic value. *Sequoiadendron*, when described by Buchholz, was carefully documented, and his tabular comparison contains an impressive total of combined generic and specific characters for his monotypic genus. This is readily available to botanists, so it does not seem necessary to quote it in full here, but it does seem appropriate to select and repeat those macroscopic characters of stem, leaf, and cone which seem of generic import.

Sequoiadendron giganteum	*Sequoia sempervirens*
Staminate cones sessile	Staminate cones stipitate
Ovulate cones remaining green and attached to tree for many years after maturity of seeds, becoming 5–7 cm. long, the axis very stout and woody, with 25–40 wedge-shaped scales that are not easily	Ovulate cones turning brown and shedding the seeds at maturity, becoming 2–3 cm. long, the axis relatively slender, with 15–20 obliquely shield-shaped scales that are easily broken off,

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broken off, terminated by a long terete spine, somewhat persistent, the scales bearing at pollination 3–12 or more erect ovules in double crescentic row, the ovules becoming 3–9 seeds in a (single or) double row on the surface of the scale, maturing the embryos in two seasons	terminated by a long flattened spine, usually deciduous, the scales bearing at pollination 3–7 erect ovules in single arched row, the ovules becoming 2–5 seeds in a single row near the margin of the scale, maturing the embryos in one season
Seeds about 200 per cone, 5–7 mm. long, with two thin wings broader than the body of the seed	Seeds about 60 per cone, 3–4.5 mm. long, with two spongy wings not as broad as the body of the seed
Buds naked	Buds scaly
Vegetative reproduction none	Vegetative reproduction abundant
Leaves all small, of only one kind, not petioled	Leaves dimorphic, the vigorous terminal shoots with small scale-like leaves; other branches with large scythe-shaped, petioled leaves
Stem habit stout, the branches turning upward at tip	Stem habit more slender, the branches horizontal or drooping

Buchholz also tabulates numerous differences in the gametophytes and in the development of the embryos.

This tabulation shows the generic characters to be numerous and impressive. A conclusion might be drawn here, but it is better to consider first other comparable pairs of genera in the Pinaceae or its segregate related families. The following have long been and are now almost universally accepted as genera:

Abies	*Picea*
Staminate cones oval	Staminate cones catkin-like
Pistillate cones erect, with the axis persistent, the stipitate scales deciduous	Pistillate cones diverging or pendant, shedding as a whole with the sessile scales attached
Cotyledons 4–5	Cotyledons 5–10
Winter buds usually resinous	Winter buds without resin
Leaves often spreading in 2 ranks, linear or linear-lanceolate, contracted above base, usually flattened and grooved above, without or rarely with stomata, with 2 (rarely 4) resin ducts, leaves without persistent leaf bases	Leaves spirally arranged, linear, usually 4-angled (or in some species 3-angled or flat), with stomata on 1 or 4 sides, with 2 or 0 resin ducts, the leaves attached by peg-like bases which are persistent on the branchlet
Cupressus	*Chamaecyparis*
Stamens with 2–6 anther cells	Stamens with 2–4 anther cells
Pistillate cone ripening in 2 seasons, scales with 15–20 seeds	Pistillate cone ripening in 1 (or 2) seasons, scales with 1–5 seeds
Seeds with narrow hard wings	Seeds with broad gauzy wings
Cotyledons 3–4	Cotyledons 2
Branchlets 4-angled (or in some species flattened or terete), irregularly disposed	Branchlets frond-like, usually flattened
Leaves scale-like, minutely denticulate-ciliate	Leaves scale-like, entire
Thujopsis	*Thuja*
Staminate flowers with 6–10 pairs of stamens	Staminate flowers with 6–12 decussate stamens
Pistillate cones subglobose, the scales 6–8 with a boss or mucro below the apex, 4–6 pairs fertile, only the upper pair sterile, the fertile scales with 3–5 seeds	Pistillate cones ovoid-oblong or ovoid, scales with an apical thickened ridge or boss, only the 2–3 middle pairs fertile, these with 2–3 seeds
Leaves decussate, the lateral ones somewhat spreading, ovate-lanceolate and curved, with glaucous white patches below	Leaves decussate, scale-like, the lateral ones nearly covering the facial ones, with or without glaucous white patches below
Tsuga	*Picea*
Staminate cones axillary, globose, anthers transversely dehiscent	Staminate cones terminal, ament-like, anthers longitudinally dehiscent
Pistillate cones 1.5–7.5 cm. long, cotyledons 3–6	Pistillate cones 2–15 cm. long, cotyledons 5–10
Leaves spirally attached, 2-ranked, flattened, and stomatiferous below or on both sides, narrowed into	Leaves spirally attached and arranged, usually 4-angled (or in a few species 3-angled or flat), with

a short petiole, in cross section with 1 resin duct below the fibrovascular bundle	stomata on 1 or 4 sides, with 2 lateral resin ducts (or none)
Taxodium	*Sequoia* (in former broad sense, including *S. sempervirens* and *S. gigantea*)
Staminate flowers in elongate spikes or panicles, scales with 5–9 sporangia	Staminate cones ovoid, terminal or axillary, scales with 2–5 sporangia
Pistillate cones subglobose or obovoid, scales 2-seeded, thick, coriaceous, peltate, the apex a 4-sided, often mucronate disc	Pistillate cones oblong-ovoid, scales 3–12-seeded, woody, wedge-shaped, often mucronate
Seeds with 3 thick wings, cotyledons 4–9, embryos 2	Seeds with 2 wings, cotyledons 2–5, embryos 2–5
Buds scaly	Buds scaly or naked
Branchlets of 2 kinds, those near apex persistent, those lower and lateral deciduous	Branchlets of 1 or 2 kinds, persistent
Short shoots persistent	Short shoots deciduous

We should probably mention the recently described genus *Metasequoia* with one living species and many fossil ones, since there is such a mass of writing on it. Its generic name would suggest a close relationship to *Sequoia*, but it has many different characters, and, significantly, the cone scales are decussate instead of spiral. It is not a close relative of *Sequoia*. The generic differences are summarized by Chaney (1951: 180).

After this review of the characters that have proved significant and acceptable for the separation of other pairs of closely related genera, we re-examine *Sequoia*. It is clear to the writers that *Sequoia* and *Sequoiadendron* are true genera, distinguished by many more contrasting, fundamental characters than those that form the basis for separation of numerous others among the widely accepted genera in the Coniferae.

Accepting, now, as genera, the two units compared, we review the nomenclature of the living species.

SYNONOMY OF SEQUOIA

Sequoia sempervirens (D. Don in Lamb.) Endl., Syn. Conif. 198, 1847.

Taxodium sempervirens D. Don in Lamb., Gen. Pinus 2: 24, 1824; also ed. 2, 2: 107, pl. 48, 1828.

Schubertia? sempervirens (D. Don in Lamb.) Spach, Hist. Nat. Vég. 11: 353, 1842. (*Schubertia* is a nomen genericum rejiciendum.)

Sequoia gigantea Endl., Syn. Conif. 198, 1847, not of Dcne. 1854 which is *Sequoiadendron giganteum*.

Sequoia religiosa Presl, Böhmische Gesell. Wiss., Abhandl. V, 6: 597, 1851; and reprinted as Epimel Bot. 237, 1851.

Condylocarpus Salisb., in Lamb., Gen. Pinus, ed. minor 2: 120, 1832, published by D. Don in synonomy of *Taxodium sempervirens* D. Don in Lamb.

Gigantabies taxifolia J. Nelson, under pseudonym Senilis, Pinac. 78, 1866.

Sequoia taxifolia Kirwan, Pinac. 246, 1868.

Steinhauera sempervirens (D. Don in Lamb.) Voss, Deut. Dendrol. Gesell., Mitt. 16 (1907): 90, 1908, the name *Steinhauera* now being a nomen genericum rejiciendum.

The customary name of this tree remains unchanged.

SYNONOMY OF SEQUOIADENDRON

Sequoiadendron giganteum (Lindl.) Buchholz, Amer. Jour. Bot. 26: 536–538, 1939.

Wellingtonia gigantea Lindl., Gard. Chron., 819–820, 823, 1853: and Hooker's Jour. Bot. & Kew Misc. 7: 26, 1855; not *Wellingtonia* Meisn. (1840) of the Sabiaceae.

Americus gigantea (Lindl.) Anon., Description of the Great Tree, recently felled upon the Sierra Nevada, California, now placed for public exhibition, in the spacious racket court of the Union Club, No. 596 Broadway, adjoining the Metropolitan Hotel, New York, p. 6–7, 1854.

Herald Job Printing Office, New York.

Sequoia Wellingtonia Seem., Bonplandia 3: 27, 1855, Feb. 1.

Sequoia gigantea (Lindl.)Dcne., Soc. Bot. France, Bul. 1: 70–71, 1854 (?Aug.; session of June 28), not of Endl. (1847) which is *S. sempervirens* (D. Don in Lamb.) Endl.

Taxodium Washingtonium Winslow, Calif. Farmer 2: 58, 1854, Aug. 24; provisional name.

Washingtonia Californica Winslow, Calif. Farmer 2: 58, 1854, Aug. 24; provisional name and nomen genericum rejiciendum; not *Washingtonia* H. Wendl. (1879), Palmae, nomen genericum conservandum.

Washingtonia Americana Hort. Am. ex Gordon, Pinetum Suppl. 106, 1862, published in synonomy.

Gigantabies Wellingtoniana J. Nelson, under pseudonym Senilis, Pinac. 79–83, 1866.

Taxodium giganteum (Lindl.) Kellogg & Behr, The Pacific, p. 53, 1855, May 7; reprinted as Calif. Acad. Sci., Proc. 1: ed. 2, 51, 1873.

Americanus giganteus (Lindl.) Anon. emend. Gordon, Pinetum 330, 1858, published in synonomy.

Sequoia washingtoniana (Winslow emend. Sudw.) Sudw., U. S. Dept. Agr., Div. Forestry, Bul. 14: 61, 1897.

Steinhauera gigantea (Lindl.) Ktze. in Voss, Deut. Dendrol. Gesell., Mitt. 16(1907): 90, 1908, nomen genericum rejiciendum, the name being based on three fossil species, known only from the cones.

The existence of the big tree was known first through the narratives of several travelers, but as they did not publish any scientific names there is no need to give the details of their observations. Hunters visited the Calaveras Grove in 1850 and 1852, but their tales of the size of the big trees were disbelieved. In 1853 Captain Hanford and William Lapham visited the grove to verify the stories. Mr. Lapham foresaw the value of the location and the public interest in the trees, so he took possession of the area and built a hotel there (Anable, 1950: 1–5).

GENERIC NAME OF THE BIG TREE

The first generic name of the big tree was *Wellingtonia*, published by Lindley (1853*a:* 819–820; 1853*b:* 823). These two articles were unsigned, but they were a part of the horticultural section of the *Gardeners' Chronicle*, the part edited by Professor John Lindley. In the first article he discussed various reputed western North American conifers, then mentioned and named the new monotypic genus *Wellingtonia gigantea*. From *Sequoia* he separated his new genus *Wellingtonia* and indicated that it was distinguished by the large size of the trunk, 250–320 feet in height and 10–20 feet in diameter, by the mature branches being round like those of the juniper, and by the cones being about 2½ inches long, 2 inches across. His informal, running account did not completely document the genus, and the trunk size mentioned was not significant, but the characters of branch and cone, listed above, were enough to serve as a description, and his name *Wellingtonia* was effectively published. Both the generic and specific names were newly coined and were not transfers from any previous publication. Lindley explained (1853*a:* 820) the appropriateness of his generic name: ". . . and we think that no one will differ from us in feeling that the most appropriate name to be proposed for the most gigantic tree which has been revealed to us by modern discovery is that of the greatest of modern heroes. Wellington stands as high above his contemporaries as the Californian tree above all the surrounding foresters [sic]. Let it then bear henceforward the name of WELLINGTONIA GIGANTEA." Professor Lindley quite misjudged the temper and the patriotism of the Americans. Numerous protests were published at the naming of the American big tree as *Wellingtonia*, and several substitute names were proposed by the patriotic Americans.

Lindley in his second account (1853*b*: 823) republished the binomial *Wellingtonia gigantea*, giving the generic characters in a formal description of six lines of Latin, then other characters which appear in his following English discussion. He contrasted his new genus *Wellingtonia* with both *Sequoia* and *Sciadopitys*, giving well-stated generic characters. Hence, these two accounts on adjacent pages presented *Wellingtonia gigantea* Lindley, new genus and species, well described and contrasted, and the whole effectively published. However, it so happened that the generic name *Wellingtonia* Lindl. was illegitimate, it being a later homonym of *Wellingtonia* Meisn. (1840) for a genus in the Sabiaceae.

The second generic name for the big tree was *Americus*, published anonymously in 1854. In that year, a cross section of a tree recently felled in California was placed on exhibit at the Union Club, New York. A pamphlet announcing the exhibit was printed to arouse interest in it and to draw spectators —". . . admission 25 cents, children half price." This was no more a scientific publication than is a circus program or a symphony orchestra program. It was anonymous, but it was printed by the Herald Job Printing Office, New York, and was dated 1854. Besides announcing the exhibit, it contained several articles, mostly reprintings of previously issued articles. The first article, on pages 4 and 5, is entitled 'The Great Tree of the Sierra Nevada, California," and is a popular account adapted from various other publications. The second article (Anon., 1854: 6–7) is entitled "Gigantic Tree in California"; it was copied paragraph after paragraph from the account in the *Illustrated London News*, February 11, 1854, which was a direct copy of Lindley's accounts in the *Gardeners' Chronicle* (1853*a*,*b*), except that in the New York pamphlet the new generic name *Americus* was substituted at every place at which the name *Wellingtonia* occurred in the originals. Thus the new binomial *Americus gigantea* Anon. was published for the big tree. This name has seldom been noticed in botanical writings. It was mentioned by Gordon (1858: 330) in the synonomy of *Wellingtonia gigantea* Lindl., but emended to the form *Americanus giganteus* Hort. Amer. This was a "corrected" version of *Americus gigantea* Anon. (1854). To someone, *Americanus* seemed preferable, but *Americus* was an equally possible name, and it had priority.

The anonymous compiler of this prospectus in which *Americus* was described obviously had little or no botanical knowledge. He was certainly unaware of the fact that Lindley's generic name *Wellingtonia* was invalid, being a later homonym. So, at that time, the big tree had no valid generic name and needed one if it was to be accepted as a new genus distinct from *Sequoia* and *Taxodium*. In any case, the generic name *Americanus* was illegitimate, having been published only in synonomy. On the other hand, the generic name *Americus* was effectively published, and the lengthy description and discussion contained ample details of description, thus validating the name.

The generic name *Steinhauera* was published by Presl (1838: 202) and applied to three new species of plants found as fossils in lignite schist in Bohemia. This name was effectively published, and the genus contained three valid binomials. Later, Kuntze decided that these fossil species belonged to the same genus as the living big tree. His combination appeared as *Steinhauera gigantea* (Lindl.) Ktze. in Voss (1908: 90). This generic name was correct then, but more recently it has been made illegitimate, being listed in the 1952 International Code of Botanical Nomenclature (Stockholm, 1950) as a nomen genericum rejiciendum, whereas *Sequoia* Endl. is made a nomen genericum conservandum. This legal action applies when the generic concept is the broad one, including in *Sequoia* both *S. sempervirens* and *S. gigantea*. It does not apply to the narrower generic concept, which we follow, that recognizes *S. gigantea* as a separate genus. However, another provision does ap-

ply. Article 68 of the same 1952 International Code says, "When a taxon of recent plants, algae excepted, and a taxon, of the same rank, of fossil or subfossil plants are united, the correct name or epithet of the former taxon must be accepted, even if it is antedated by that of the latter." This applies exactly to the issue at hand and rejects the name *Steinhauera* for our living trees.

The next name for the big tree was *Gigantabies*, with the apparent binomial *Gigantabies Wellingtoniana* [J. Nelson] published under the pseudonym Senilis. This appeared in a privately printed book, offered for sale for 10/6 by Johannes Senilis, Lymington, Hants. It is recorded in English bibliographic sources that the author's real name was John Nelson. The book title is "Pinaceae: being a handbook of the firs and pines," and it was published (1866) in London by Hatchard and Company. This book was soon reviewed, apparently by the editor, in the *Gardeners' Chronicle* (1866: 542) and wholly condemned: "The truth is, the author is not qualified for writing a book upon Conifers. The reader can judge of his literary qualifications from the verbose ungrammatical sentences which we have above quoted. His qualifications for dealing with the subject he has chosen are still less. He appears to be unacquainted with the very elements of Botany and Physiology; seems not to have the most distant idea of the principles on which, by the labours of many minds of the highest talent, the present system of systematic botany has been based; does not know what has been already done, what has been already proposed and rejected by general consent, and why. He has, apparently, in his present condition no one qualification which suits him for such a work." Nelson put the redwood under the same name, *Gigantabies*, and gave it the new name *Gigantabies Taxifolia*. If taken as a generic name, *Gigantabies* must be placed as a later synonym of *Sequoia*, because *G. Taxifolia* was only a renaming of the earlier *S. sempervirens* (D. Don in Lamb.) Endl. Nelson did not cite *S. sempervirens* in synonomy, but he did mention the early collections of it by Menzies, Douglas, Hartweg, and the Russians; located it in California, particularly on the Santa Cruz range; and by his lengthy description made abundantly clear that his new tree was the well-known redwood, *Sequoia sempervirens*. Article 16 of the 1952 International Code reads: "For any taxon from order to genus inclusive, the correct name is the earliest legitimate one validly published with the same rank. For any taxon below the rank of genus the correct name is the combination of the generic name with the earliest available legitimate epithet or epithets validly published with the same rank." By these legal provisions, *Gigantabies Taxifolia* J. Nelson is illegitimate.

We could dispose of the remaining name *Gigantabies Wellingtoniana* on the same grounds, but if the big tree was accepted as a distinct genus, it was at this time nameless, hence the status of the name *Gigantabies* needs scrutiny. After some initial poems, Nelson came to his technical treatment of the Pinaceae which he subdivided into divisions, subdivisions, sections, sub-sections, and species, and we quote (pp. 26–27).

TECHNICALITIES used in the CLASSIFICATION and NOMENCLATURE

S.D., (SUB-DIVISION.) A cognate family containing few or many specifically distinct *species*, and of these there may be a few, or many *quasi-species*, *varieties*, and *sub-varieties*.

SECTION, I use as a group of a S.D. having numerous and dissimilar *species*, and which are arranged in *sections* having some peculiarity or other, as distinguishing one *section* from another in the S.D. to which they belong. SUB-SECTION I use after the same manner as *section*. . . .

SPECIES, as a specifically distinct tree or plant, having one or more well marked and constant characteristics, distinguishing it from the other *species* of a S.D.; and which reproduces itself true from seed.

CLASSIFICATION.

ARRANGEMENT.

Pinaceae

Division I.—CONIFERAE.—CONE-BEARING FIRS AND PINES.

Division II.—BACCIFERAE.—BERRY AND FRUIT-BEARING PINES.

CONIFERAE

S.D. I.—ABIETINEAE.—The Fir Tribe.

§ 1. **Intermedia.**—The Intermediate Fir.
§ 2. **Picea.**—The Pitch or Silver Fir.
§ 3. **Vera.**—The True or Spruce Fir.

S.D. II.—CEDRUS.— The Cedar.

S.D. III.—CUPRESSINEAE.—The Cypress Tribe.

§ 1.—**Actinostrobeae.**—The Rayed-scaled Cypress
Sub. § 1.—OCTOVALVUS.—Eight-valved.
Sub. § 2. SEXAVALVUS.—Six-valved.
Sub. § 3.—QUARTOVALVUS.—Four-valved.
§ 2.—**Arthrotaxia.**—The Jointed-branched Cypress.
§ 3.—**Cryptomeria.**—The Cedar-like Cypress.
§ 4.—**Cupresstellata.**—The Star-coned Cypress.
§ 5.—**Cuprespinnata.**—The Feathery-sprayed Cypress.
§ 6.—**Thuriferae.**—The Arbor Vitae.
Sub. § 1.—BIOTA.—The Oriental.
Sub. § 2.—LIBOCEDRUS.—The very Fragrant.
Sub. § 3.—THUJA.—The Occidental.
§ 7.—**Verae.**—The True Cypress
Sub. § 1.—CHAMAECYPARIS.—The Ground Cypress.
Sub. § 2.—CUPRESSUS.—The Prototype.
Sub. § 3.—RETINOSPORA.—Resinous-seeded.

S.D. IV.—GIGANTABIES.—The Giant or Mammoth Fir.

By his arrangement *Biota*, *Libocedrus*, *Thuja*, *Chamaecyparis*, *Cupressus*, and *Retinospora* were made sub-sections; *Picea* and *Cryptomeria* were made sections; *Abietineae*, *Cedrus*, *Cupressineae*, and *Gigantabies* were his four sub-divisions; and *Coniferae* and *Bacciferae* were his two divisions. Genera, well accepted by botanists, were by Nelson made sub-sections, sections, or sub-divisions. In the taxonomic treatment, specific names were combined with all of these, forming apparent binomials. *Gigantabies Wellingtoniana* is one such. Surely, the combination of the name of a species with that of a sub-division does not make a binomial. Applicable sections of the 1952 International Code are: Article 13, "A plant may therefore be classified in subordinated categories in the following order: Regnum vegetabile, Divisio, Subdivisio, Classis, Subclassis, Ordo, Subordo, Familia, Subfamilia, Tribus, Subtribus, Genus, Subgenus, Sectio, Subsectio, Species." Then by Article 15, "The relative order of the categories specified above in Art. 12–14 must not be altered.

"Names given to taxa which are at the same time denoted by misplaced terms are treated as not validly published. . . ."

So, *Gigantabies* was not a generic name; *Gigantabies Wellingtoniana* was not a binomial, and the whole is illegitimate.

Finally, the generic name *Sequoiadendron* was published for the monotypic genus of the big tree, by Buchholz (1939: 536). This was based upon *Wellingtonia gigantea* Lindl. and included the concepts and the synonyms published by Winslow, Decaisne, Seemann, Kellogg & Behr, Sudworth, and Kuntze. The generic name was effectively published and was accompanied by a Latin diagnosis, a type species was designated, and there was given a fully detailed comparison with *Sequoia* which he interpreted as represented by only one living species, the redwood, *S. sempervirens*.

Sequoiadendron of Buchholz has now had some acceptance, as by Rehder (1940: 48–49; 1949: 41), L. H. & E. Z. Bailey (1941: 680), Rickett (1950: 15), and Stebbins (1948: 95), and reaffirmation by Buchholz (1948: 90).

The investigation by Buchholz was careful, detailed, and original. It revealed many morphological characters that were unknown before. It detailed the many important differences between the big tree and the redwood. Buchholz classified the big tree as a separate genus and published for it the name *Sequoiadendron*. We have reviewed the same investigation and concur that *Sequoiadendron* is a good and distinct genus. The only flaw is in priority, as there is an earlier name, *Americus*.

On every score the generic name *Americus* deserves to be outlawed. It was published in an anonymous advertising circular. It was seen by few botanists and was adopted by none. The pamphlet is excessively rare now; the copy consulted for us is in the library of the New York Botanical Garden. The anonymous writer made no botanical study of the tree or its trunk. He wrote no description of the tree, merely copied the one validating *Wellingtonia gigantea*. The only item contributed by the anonymous writer was the sub-

stitution of the name *Americus* for each occurrence of *Wellingtonia* in the original article by Lindley. He did not assert that the name *Wellingtonia* was illegitimate. That a new generic name was needed was an accident quite unknown to the anonymous writer. Neither the man nor the name deserves recognition. We think there is every reason for making the generic name *Americus* a nomen genericum rejiciendum. We propose that the next International Botanical Congress adopt *Sequoiadendron* Buchh. as a nomen genericum conservandum, and treat *Americus* as a nomen genericum rejiciendum.

SPECIFIC EPITHET OF THE BIG TREE

Though the waters one must traverse in reviewing the generic history of the big tree may seem somewhat turbid, they are nothing in comparison to the muddy, swirling waters one must sail over in the historic quest of the correct specific epithet.

It was long thought that the first scientific name for the big tree was *Sequoia gigantea* Endl. (1847: 198). This was rejected by Buchholz, as it had been by many others, but it needs careful analysis and discussion to dispose of it fully. We quote its original treatment in full:

2. SEQUOIA GIGANTEA ENDL.

Sequoia foliis linearibus (1½–2″) acutis subtus glauco pulverulentis.

Taxodii species Douglas in Bot. Mag. Comp. II. 150.

Abies religiosa Hook. et Arnott ad Beechey 160. non Humb.

Taxodium sempervirens Hook. et Arnott ad Beechey 392. Hooker Ic. t. 379. Habitat in California. (Dougl.)

Arbor trecentorum pedum altitudinem attingens, trunci ambitu trigintapedali.

In this same passage Endlicher described the new genus *Sequoia*, and his species No. 1 was called *S. sempervirens* Endl. [or as the authority should now be written, (D. Don in Lamb.) Endl.], the accepted name of the redwood, though his basonym was briefly attributed only to Lambert.

Now, for *S. gigantea* Endl. The original publication included a description, a statement of the type locality (stated as habitat), and a collector, and the first synonym, *Taxodii* species, all of which rest upon the work of Douglas. Then, finally, there are two other synonyms which rest upon the work of Hooker and Arnott, and of Hooker, and a diagnosis. Let us first consider these last two synonyms:

Abies religiosa Hook. et Arnott ad Beechey 160, non Humb. This, in the sense of Hooker and Arnott, is a mixture of several diverse species and genera, but it includes only the following reference to Californian trees, "I was informed that there are trees of this species in the vallies between Santa Clara and Santa Cruz, 150 feet high, one of which was 25 feet in circumference." This is the only element in *Abies religiosa* sensu Hook. & Arn. which may have been based on *Sequoia* and might be selected with that in view to typify their specific concept. However, the only description given is that of the stature, 150 feet high and 25 feet in circumference, and this was only a hearsay report. That would apply to a young specimen of the big tree, but is in no way distinctive of it, and certainly is incorrect as a description of the full stature of a mature or large specimen of the big tree which is 250–330 feet in height and 40–56 feet in circumference at 10 feet above the base, or up to 90 feet at 6 feet above the base. The locality given, "in the vallies between Santa Clara and Santa Cruz," is far distant from any known grove or occurrence of the big tree, all of which are east of the central valley of California and at 4,600–8,500 feet altitude on the western slopes of the Sierra Nevada Mountains. On the other hand, both the stature and the locality given by Hooker and Arnott tally exactly with the size and a well-known, still existing stand of the redwood, *Sequoia sempervirens*. It is clear, then, that the only meager element in *Abies religiosa* sensu Hook. & Arnott, not of H.B.K., which applies to a Californian gymnosperm was probably in allusion to *Sequoia sempervirens*

and certainly did not apply to the big tree. The first use of the name *Abies religiosa* (H. B.K.) Schlecht. & Cham. (*Linnaea* 5: 77, 1830) was based upon *Pinus religiosa* H.B.K. (*Nov. Gen & Sp.* 2: 5, 1817). This tree, still accepted as *Abies religiosa*, is native to the highlands of Mexico at from 1,200 to 3,450 meters altitude, from Durango and the Valley of Mexico south to Guatemala. It was named *religiosa* because of the traditional use of its branches to decorate the churches of its region. Obviously, the usage by Hooker and Arnott was a misapplication of the name *Abies religiosa*, the true usage of which is for a true fir tree, or "oyamel" of the Mexicans, a tree native to the mountains of Mexico and Guatemala.

The third synonym listed in the publication of *Sequoia gigantea* Endl. was "Taxodium sempervirens Hook et Arnott ad Beechey 392. Hooker Ic. t. 379." *Taxodium sempervirens* sensu Hook. & Arn. was printed in *The Botany of Captain Beechey's Voyage*, p. 392, 1840, and was merely a later usage of *T. sempervirens* D. Don in Lamb., the basonym of *Sequoia sempervirens* (D. Don in Lamb.) Endl., the accepted name for the redwood. Though we are dealing with a later usage of a previously published and valid name, we should examine the basis of the usage by Hooker and Arnott in 1840. Their publication was as follows:

1. *Taxodium sempervirens* Lamb. Pin. t. 643? Hook. Ic. Pl. ined.-Abies religiosa. supr. p. 184 (an Cham. et Schlect?)

Of this we have seen no flowers nor fruit, and the leaves are nearly twice the length of those figured in Mr Lambert's work, shining on the upper side as in *Podocarpus*, and glaucous underneath. The tips of the branches exhibit buds formed of imbricated membranaceous concave shining scales, which resemble the scales at the base of the galbule in Lambert's description and figure quoted. Our plant is obviously what Douglas alludes to in his Journal (Comp. Bot. Mag. vol. II. p. 150.) in the following words:—"But the great beauty of the Californian vegetation is a species of *Taxodium*, which gives the mountains a most peculiar, I was almost going to say awful, appearance,—something which plainly tells that we are not in Europe. I have never seen the *Taxodium Nootkatense* of Née, except some specimens in the Lambertian herbarium, and have no work to refer to; but from recollection, I should say that the present species is distinct from it. I have repeatedly measured specimens of this tree 270 feet long, and 32 feet round at three feet above the ground. Some few I saw upwards of 300 feet high, but none in which the thickness was greater than those I have instanced."

Taxodium sempervirens sensu Hook. et Arnott rested on four elements:

1. The name, and a reference to *T. sempervirens* Lamb., the basonym of *Sequoia sempervirens*, the redwood.

2. A reference to a plate prepared for Hooker's Icones, but then unpublished. This later appeared in volume 4: t. 379, 1841. It represented a sterile branch, collected by Lay and Collie in California, now identified as *Abies bracteata* (D. Don in Lamb.) Nutt. (1849), according to Rehder (1949: 647). The Latin diagnosis, a line and a third in length, given for *Sequoia gigantea* Endl., "foliis linearibus (1½–2″) acutis subtus glauco pulverulentis," bears no resemblance to the characters of the big tree or to the small, bright yellow-green foliage of the redwood. It is apparent that Endlicher took these characters from the passage by Hooker and Arnott in *The Botany of Captain Beechey's Voyage*, where they wrote, ". . . the leaves are nearly twice the length of those figured in Mr Lambert's work, shining on the upper side as in *Podocarpus*, and glaucous underneath." Then, the diagnosis given by Hooker for *Sequoia gigantea* applied to *Abies bracteata*.

3. A reference to *Abies religiosa* sensu Hook. et Arnott, and doubtfully sensu Cham. & Schlecht. Our discussion just above points out that *Abies religiosa* (H.B.K.) Cham. & Schlecht. is a true fir tree, native of Central America. The sterile branch collected by Lay and Collie in California, indentified by Hooker and Arnott as *A. religiosa*, is now considered to represent a misidentified specimen of *Abies bracteata* Nutt.

4. A duplicated reference to *Taxodium* species of Douglas, which will be discussed below.

Now, reverting to the major elements of *Sequoia gigantea* Endl., the description, local-

ity, and collector, all of which allude to David Douglas and his *Taxodium* species. Douglas himself published no species of *Taxodium*. He was a very capable taxonomist and in his few months in London published papers and prepared manuscripts evidencing ability and productivity in this technical work. He was supreme as an explorer and botanical collector and left his indelible mark on the botany of North America and of the Pacific. He might well have published upon his observed *Taxodium*, but he perished on a mountain side in the Hawaiian Islands, apparently by murder. Douglas was an explorer, working for the Royal Horticultural Society of London, and he reported to it. One of his letters written at Montérey, Upper California, dated November 23, 1831, was published by Hooker (1836: 150), "But the great beauty of Californian vegetation is a species of *Taxodium*," etc. This passage was quoted by Hooker and Arnott, and above we quote their version which was complete, except that they omitted the following last sentence: "I possess fine specimens and seeds also." We discard Douglas' reference by memory to *Taxodium nootkatense* Nees, a name even yet unpublished, though Douglas may have known it as a manuscript name. Doubtless it was synonymous with *Cupressus nootkatensis* D. Don in Lamb. (1824), now accepted as *Chamaecyparis nootkatensis* (D. Don in Lamb.) Sudw. (1897), the Alaska cedar. Douglas' allusion was a misidentification based on a vague memory of that coastal tree of northwestern America. That leaves in his passage only his statements concerning the awesome Californian tree species that he had seen, 270 or more than 300 feet tall and 32 feet in circumference 3 feet from the ground. He collected fine specimens and seeds. Doubtless these were sent to England, but they did not arrive. No such plant is included in the list of plants introduced by Mr. Douglas in 1834. A subsequent collector, William Lobb, who followed Douglas to Northwest America and California, wrote as follows, and the letter was published by Lindley (1854: 22): "I am well acquainted with every part of the country trod by Douglas . . . seldom 30 miles from the coast and 160 or more from the nearest big tree." Lindley continued, "It is therefore evident that no materials exist for determining what DOUGLAS really meant by his 'Taxodium,' which may or may not have belonged to that genus, or, as ENDLICHER conjectured, to Sequoia. But species in natural history cannot be founded upon conjecture." Thus, it is clear that Douglas on his trips never approached any of the big tree groves, and that his specimens which were probably of the redwood were lost in transit to England. The few descriptive words of his that were published posthumously are only measurements of some large trees, and they tally well with the dimensions and proportions of the redwood which was common in the regions he traversed. In sum, there is no part of the *Taxodium* species mentioned by Douglas that can be demonstrated to apply to the big tree. Consequently, *Sequoia gigantea* Endl. (1847) is in larger part a synonym of *S. sempervirens* and, in smaller parts, of *Abies religiosa* (H.B.K.) Schlecht. & Cham. and *Abies brecteata* (D. Don in Lamb.) Nutt. No part of it has been demonstrated to be based on the big tree, so it is impossible to typify the species by any fragment of the original concept which action might preserve the epithet for application to the big tree.

As we have demonstrated earlier, the generic name *Wellingtonia* of Lindley was a later homonym and hence illegitimate. For those who still retain the big tree and the redwood in the single genus *Sequoia*, this specific epithet *gigantea* of Lindley is not available, as on transfer to *Sequoia* it becomes a later homonym of *S. gigantea* Endl., which is in larger part a synonym of *S. sempervirens*. If the big tree is best classified as a distinct genus, whether called *Americus* or *Sequoiadendron*, the epithet *gigantea* of Lindl. is available in either combination.

Sequoia gigantea (Lindl.) Dcne. (1854: 70–71), the next binomial, appeared in a pub-

lished account of remarks by Decaisne at a meeting of the Société Botanique de France. He demonstrated specimens of the redwood and of the big tree, referred to *Wellingtonia* Lindl., discussed the distinctive botanical characters, disagreed with Lindley that they formed two genera, then gave his conclusion that they were *Sequoia sempervirens* and *Sequoia gigantea*. This latter binomial has long been taken as *Sequoia gigantea* Dcne., but it seems actually a transfer, *Sequoia gigantea* (Lindl.) Dcne., based upon *Wellingtonia gigantea* Lindl., and it has already been so interpreted by Little (1944: 276). Another interpretation might be that *Sequoia gigantea* Dcne. was an independent new species, based upon a description solely of the specimens at hand, sent to the Paris Museum by M. Boursier de la Rivière, consular agent of France. These possible interpretations lose their importance when it is realized that the specific epithet is invalid in either case, being a later homonym of *Sequoia gigantea* Endl. (1847: 198).

In 1854 the binomial *Americus gigantea* (Lindl.) Anon. was published. We have previously dealt with the new generic name. The specific epithet was obviously one transferred from *Wellingtonia gigantea* Lindl. and was based upon the same description and specimens. It did not provide a new specific name.

Two other new binomials were published in 1854. The name *Taxodium Washingtonium* Winslow was printed in a weekly newspaper called the California Farmer (Winslow, 1854: 58), and in the same paragraph another name, *Washingtonia Californica* Winslow, was proposed. These names have been given varied treatments, accepted, corrected, or rejected, by various botanists. As this local farm newspaper is not readily available to botanists and as the exact wording of the proposals of Winslow is decisive, his whole one-page article is reproduced here (Fig. 1). It was a letter written by Dr. C. F. Winslow on August 8, 1854, from Washington Mammoth Grove [or Calaveras Grove]. It was a description of his 15-mile trip by carriage road, the incidents of the trip, and his impressions, stated at length in an elaborate and flowery style of writing. He stated the size of several of the big trees and quoted many details told him by the hotel proprietor. He gave a few descriptive details of leaves and cones. He alluded to the publication by the English botanist, Professor Lindley, of the tree as *Wellingtonia Gigantea*, but objected that this generic name honoring an English military hero was distasteful to and unacceptable by Americans. Then Winslow renamed Lindley's *Wellingtonia Gigantea* as follows: "If the 'Big Tree' be not a Taxodium, let it be called now and forever *Taxodium Washingtonium*. If it should be properly ranked as a new genus, then let it be called to the end of time, *Washingtonia Californica*. The generic name indicates unparalleled greatness and grandeur; its specific name, the only locality in the world where it is found. No names can be more appropriate, and if it be in accordance with the views of American botanists, I trust the scientific honor of our country may be vindicated from foreign indelicacy by boldly discarding the name now applied to it, and by affixing to it that of the immortal man whose memory we all love and honor, and teach our children to adore. . . . Under any and all circumstances, however, whether of perpetuity or extinction, the name of Wellington should be discarded and that of WASHINGTON attached to it, and transmitted to the schools of future ages."

Now, to consider the two binomials published by Winslow. They were immediately reduced to the synonymy of his own *Sequoia Wellingtonia* Seem. by Seemann (1858: 345–346) in his second and extensive account of the tree, and he pointed out that the big tree had already been named as a genus by Lindley in 1853 and as a species by himself in February, 1855. Winslow's names fell into the discard and received little attention. It appears that most of those botanists who have considered his names at all have not consulted his original newspaper account, but one of the two reprintings of it that appeared in

meritorious, although they may not be named in the list of premiums.

Each Committee is authorized to recommend special premiums upon objects that properly belong to the class assigned to them.

The managers of the Society will be present during the Fair to give directions to all who may wish to enter animals or any articles for premium or exhibition, and forage will be furnished gratis for all animals entered for premiums.

The Society earnestly desire to be informed, at the earliest possible moment, how far the different Farmers in the State can co-operate in this undertaking, and what specimens they intend to exhibit—so that suitable provision may be made for their contributions.

All communications upon the subject, will be promptly responded to, and all information cheerfully rendered.

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Dr. C. F. Winslow's Letters from the Mountains.

THE "BIG TREE."

WASHINGTON HARMONY GROVE, }
August 30, 1854. }

DEAR SIR: At half-past three P. M. yesterday, we started from Murphy's for the Big Tree, on the stump of which I am now writing. The ride is fifteen miles long, and is one of the most varied and charming which I have ever enjoyed. At first you follow a ravine for several miles, hedged in by sloping and rounded hills, sparsely wooded with varieties of the conifera; and in the bottom of this winds a clear brook; which forms the stream of the Union Water Company, for supplying the miners with water during the dry season at Murphy's Camp. Subsequently the beautiful ravine opens into a broad vale, which at last is lost in the gentle slopes and varying aspects of landscape that swell and charm the eye in all directions. A great variety of pines, oaks and other trees and shrubs add finish and endless charm to this fresh and virgin landscape. After gradually ascending for some miles by a winding and well made carriage road, you reach points where the lofty and magnificent pines open and afford prospects of distant mountain slopes and summits, covered to the uppermost ridge with such grand and magnificent coniferous forests that I will not attempt to describe them. The sun shone with heated and golden beams, and the light, softened and mellowed by the radiating vapors of the highlands, lent tints to the verdant wilderness and towering ridges which heightened the charms and magnificence of the broad and wild panorama. The road was more or less shrouded all the way by pines so gigantic as to awaken in me, who had never before seen the native and lofty forest scenery of the north temperate zone, the strongest feelings of wonder and admiration. I had never before conceived of the capacity of the various species of conifera to attain such enormous dimensions. They were often six feet through, and from one hundred and thirty to three hundred feet high, and so symmetrical and perfect in form as to impress me with new and more commanding ideas respecting the force and operation of the vital principle presiding over the nourishment and growth of organized bodies. The delicate and symmetrical development of some of these towering and gigantic vegetable forms filled the mind with emotions of the beautiful, similar to those felt at beholding the most perfect models of the human form wrought from marble or delineated on canvass. There they stand against the deep blue sky, cell having been added to cell by slow processes of growth, fashioned by the breath of the Almighty, until they have attained such strength as to defy the ordinary methods of violent destruction. All along the last few miles of the road I was filled with impressions wholly new, and often involuntarily surrendered myself to the idea that I was approaching the visible and actual presence of the Great One, who realized himself to Moses on the heights of Sinai. Such sublime thoughts have rarely impressed my soul, and it is only here, in the midst of these living wonders of the mountain forests, that such conceptions have been awakened to their complete height of grandeur and awe. On the summit of these lofty mountains, amid the columns of this great temple of nature, I am compelled to bow down and acknowledge the utter nothingness of mortal man and the infinite greatness of the power that hovers around the globe and weaves a germ from the dust of the earth that shall outlast sixty human generations. But another order of reflections crowd upon the mind. What changes have transpired in the condition of people and of States since the germ shot down the root on which I reared these thoughts. The golden age had not yet dawned on the Roman empire, and the ancesters of the present polished races of Great Britain, France and Germany, were naked and wandering savages in the bleak and snowy forests of northern Europe. Within this time the man of Nazareth and the prophet of Mecca have overturned the dogmas and idolatrous worship of the benighted nations of Asia and Europe, and, like the waves of the ocean, little and great kingdoms have arisen, and, melting away, mingled their elements with each other, until no trace exists of their former bounds or grandeur. How strangely interesting are all these multitudinous events when crowded by contrast into a space of time occupied by the growth and life of a single tree on these Alpine and lonely heights. If the lifetime of a single vegetable germ shall outlast and look down on all these stripes and transactions of the races of man for two thousand years; how ancient must be the earth, the parent and the stage of them all?

The height of this spot above the ocean is rather less than five thousand feet, and it is two thousand four hundred feet above Murphy's Camp. The road, gradually ascending for several miles over a varied landscape, becomes afterwards more level, or rather it undulates and winds for a long stretch among hills and vallies thickly wooded and fit for farms and deer parks. During the last three miles the ascent is steady and through a virgin wilderness of pines, firs, spruce, arbor vitæ and other cone bearing trees, whose magnitude perceptibly increases with the altitude of the locality. The whole surface of the hill sides is covered with herbage or plants, more or less verdant, and in spots there is a freshness to the verdure which reminds one of spring, and which contrasts strongly with the arid and dusty plains and hills of the lower sections of country. The wild raspberry, strawberry, pea and hazelnut mingle their humble or more prominent foliage with the diversified undergrowths of the forests, and here and there new and attractive flowers struck my eye so pleasingly that I was compelled at times to stop, gather, examine and admire them. The charm of these regions to the botanist would be in the freshness and luxuriance with which nature elaborates her vegetable forms. The vital principle, stimulated by the condensing vapors of the cool fresh of night, and nourished by a suitable pabulum in the decomposing soil, acts with a steady energy, and thousands of stately trees stud the hills in all directions, so lofty as to amaze the observer and to compel him when near them to strain his eyes to catch a view of their topmost offshoots. But the most amazing of all these vegetable productions is here, and nature, by peculiar prognostic arrangements, seems to have isolated them to startle and arrest the attention of mankind, and to strengthen scientific truth, teaching the special distribution of organic races. So far as known, the vegetable growth to which the name of "Big Tree" has been attached, grown in no other region of the Sierra Nevada, nor on any other mountain range of the earth. It exists here only, and all the individuals of its kind, so far as I can learn, are localised to this vicinity. They are embraced within a range of two hundred acres, and are enclosed in a basin of coarse siliceous material, surrounded by a sloping ridge of granitic rock, which in some places projects above the soil. The basin is working with moisture, and in the lowest places the water is standing, and some of the largest trees dip their roots into the pools or water-runs. The trees of very large dimensions number considerably more than one hundred. Mr. Blake measured one ninety-four feet in circumference at the root; the side of which had been partly burnt by contact with another tree, the head of which had fallen against it. The latter can be measured four hundred and fifty feet from its head to its root. A large portion of this fallen monster is still to be seen and examined; and by the measurement of Mr. Lapham, the proprietor of the place, it is said to be ten feet in diameter at three hundred and fifty feet from its upturn root. In falling it had prostrated another large tree in its course, and pressed out the earth beneath itself so as to be imbedded a number of feet into the ground. Its diameter across its root, is forty feet. A man is nothing in comparison of dimensions, while walking on it or standing near its side. This to me was the greatest wonder of the forest. The tree which it prostrated in falling has been burnt hollow, and is so large, a gentleman who accompanied me from Murphy's informed us, that when he first visited the place two years ago, he rode through it on horseback for 200 feet without stooping, but at one spot as he entered at the root. We all walked many scores of feet through it, but a large piece of its side has fallen in near the head. But there are many standing whose magnitude absolutely oppress the mind with awe. In one place, three of these gigantic objects grow side by side, as if planted with special reference to their present appearance. Another so monstrous as to absolutely compel you to walk around it, and even linger, is divided at from fifty to a hundred feet from the ground into three of these straight mammoth trunks, towering over three hundred feet into the sky. There are others, whose proportions are as delicate, symmetrical, clean and straight as small spruces, that rise three hundred and fifty feet from the ground. In one spot a huge knot of some ancient prostrate giant is visible above the soil, where it fell ages ago, and the earth has accumulated so as nearly to obliterate all traces of its former existence. The wood of this tree, I am told by Mr. Lapham, is remarkable for its slow decay. When first cut down its fibre is white, but it soon becomes reddish, and long exposure makes it as dark as mahogeny; it is soft and resembles in some respects pine and cedar. Its bark, however, is much unlike these trees; nearest the ground it is prodigiously thick, fibrous, and when pressed on has a peculiar feeling of elasticity. In some places it is eighteen inches thick, and resembles a mass of cocoa-nut husks thickly matted and pressed together, only the fibrous material is exceedingly fine, and altogether unlike the husk of the cocoa-nut. This bark is fissured irregularly with numerous indentations, which give it the appearance of great inequality and roughness. A hundred and fifty feet from the ground it is only about two inches thick on the living tree, which is now being stript of its bark for transportation from the country.

The cone of this tree is small and compact, and nearly regularly oval; and although the tree itself is the largest of the conifera, its fruit is as small as that of the dwarfish pines of North Carolina and Cape Cod. Its foliage is not, as a general thing, altogether agreeable to the eye, as the head of the tree is small in proportion to the size and height of the trunk. But the boughs, when examined more closely, are bright-green, rather complicated and delicate in structure, and pleasing to the mind by contrast with the rough and gigantic stem and branch from which they spring.

The name that has been applied to this tree by Prof. Lindley, an English botanist, in Wellingtonia Gigantea. By him it is declared to be so much unlike other conifera as not only to be a new species, but to require description as a new genus. Other botanists, of eminence, think differently. To this, however, he has seen fit to apply the name of an English hero, a step indicating as much personal arrogance or weakness as scientific indelicacy; for it must have been a prominent idea in the mind of that person that American Naturalists would regard with surprise and reluctance the application of a British name, however meritoriously honored, when a name so worthy of immortal honor and renown as that of WASHINGTON would strike the mind of the world as far more suitable to the most gigantic and remarkable vegetable wonder, indigenous to a country, where his name is the most distinguished ornament. As he and his generation declared themselves independent of all English rule and political dictation, so American Naturalists must in this case express their respectful dissent from all British scientific "stamp acts." If the "Big Tree" be not a TAXODIUM, let it be called now and forever TAXODIUM *Washingtonium*. If it should be properly ranked as a new genus, then let it be called to the end of time, *Washingtonia Californica*. The generic name indicates unparalleled greatness and grandeur; its specific name, the only locality in the world where it is found. No names can be more appropriate, and if it be in accordance with the views of American botanists, I trust the scientific honor of our country may be vindicated from foreign indelicacy by boldly discarding the name now applied to it, and by affixing to it that of the immortal man whose memory we all love and honor, and teach our children to adore. Before many ages shall elapse the reckless hand of man, or climatic changes, may totally annihilate the few giants of this remarkable race now growing on and confined to this small basin in the Sierra Nevada. Seeds indeed may be planted and means employed to prolong its existence elsewhere, but few spots of earth, perhaps none, will be so eligible for its natural and complete development as its present locality. Under any and all circumstances, however, whether of perpetuity or extinction, the name of Wellington should be discarded, and that of WASHINGTON attached to it, and transmitted to the schools of future ages.

At this place is a very excellent public house, kept by an urbane proprietor, who spared no pains to interest us and give all information in his power. The half I heard or saw, I have not noted here. The hotel is built near the "Big Tree" whose bark was stripped last year and exhibited in San Francisco. An appendage of the house is built over it, and it constitutes a hall for cotillion parties; at the root it measures ninety-six feet in circumference, and a portion of its prostrate trunk is used for a bowling alley. To overthrow it, holes were bored through it with a large auger, and after the trunk was mostly separated, attempts were made to wedge and upset it. But its immense size and weight prevented the success of this undertaking; and on the fourth day it fell by the force of a strong wind. In falling, it convulsed the earth, and by its weight forced the soil from beneath it so that it lies in a great trench, and mud and stones were driven near a hundred feet high, where they have left their marks on neighboring trees.

The coolest, purest, choicest water in the world is here. I have never tasted such water in all my wanderings over the earth. The well that supplies it is sunk twenty-two feet, through coarse scientic mud and fine angular gravel, apparently the mere unwashed detritus of the neighboring ridges of the basin, and the water stands twelve feet deep in the well.

Here we spent the night; rose early and inspected the forests, and contributed a large share of blood for the maintenance of the numerous musketoes that infest the luxuriant under-growths of the moist and teeming soil. The abundance of these pertinacious and venomous creatures was the only drawback to our enjoyment; but I have seen them no where else, away from the delta, and even during the night the cool temperature destroyed their activity here.

The night spent here was delightful. The moon shone with unparalleled splendor, and the atmosphere was so pure that it seemed as if the stars of heaven had quadrupled in number. I shall never forget this night, nor the first glimpses of the rising moon as her mild and pensive beams penetrated the waving foliage of two mighty giants not far from me. O glorious orb! how thou stealest the heart from strong men's breasts, and on thy luminous beams transportest it athwart a continent and layest it down in the silent chambers of the beloved! Only assure us that thou lendest it thy pencils to paint pleasant dreams on the slumbering souls of the little and the weary, and we will yield it gladly and rejoicingly to thy benign sway. As silent as is thy voice and influence, so sweetly shall that heart pass to its repose; and the images of the distant and beloved shall rise or vanish as thy beams brighten or the night grows dark.

Respectfully, yours, C. F. WINSLOW.

RAIN IN SACRAMENTO.—We were at our "Home" in Sacramento on the morning of the 21st, and were surprised on awakening to find a cool, cloudy morning—and at 6 A. M. to find the rain falling as gently as one of our old fashioned "April showers," in New England. After the preceding hot Sunday, the change was most agreeable. The air had a most delicious freshness—the birds sang their songs anew—children awoke merrily—the lambs were seen to sport frolicly, and nature robed herself with a clean blue above and a bright green beneath. O there was a freshness that made all feel happy, for the memory of such showers and the scenes of by-gone days, and the tear-drop stood in the eye of all, like as the dew-drop upon the new opened flower.

TO REMOVE MARKS FROM TABLES.—Hot dishes sometimes leave whitish marks on varnished tables, when set, as they should not be, carelessly upon them. To remove it, pour some lamp oil on the spot, and rub it hard with a soft cloth. Then pour on a little spirits, and rub it dry with another cloth, and the white mark will disappear, leaving the table as bright as before.

FIG. 1. Original description by Winslow of *Taxodium Washingtonium* and *Washingtonia Californica*.

Hooker's Journal of Botany and Kew Garden Miscellany (7: 29, 1855); and this reprint was reprinted in the *Gardeners' Chronicle and Agricultural Gazette* (1: 7–8, 1855, January 6). In both of these, the significant phrase appears as, "If the 'Big Tree' be a Taxodium, let it be called . . . *Taxodium Washingtonium*." Thus, the editors had altered the quoted passage, removing the negative that was in the original by Winslow, viz: "If the 'Big Tree' be *not* [italics ours] a Taxodium, let it be called now and forever *Taxodium Washingtonium*." Winslow wrote well-phrased and grammatical English, so there is little doubt but that if he had been allowed to proof-read his letter before publication he would have removed the "not" which made the sentence nonsensical. If he deemed the tree not to be a *Taxodium*, why would he coin a name for it in that genus? Two generations later, G. B. Sudworth revived this first name of Winslow's, but he altered its spelling to *Sequoia washingtoniana* (Winslow) Sudw. (1897: 61–62). Here he made the new combination without explanation or discussion, but later (1898: 28–29; and 1927: 32–33) again used the name and here gave a lengthy explanation. He found the name valid under Article VI of the Rochester Code of Nomenclature, which he was following. That code is no longer used, but Sudworth's concluding paragraph concerning this article is worth quoting.

> In interpreting the fundamental object of this article cited for the publication of species and applying it to all cases likely to arise, it would seem the duty of the interpreter to abide by the principle involved in the law, and to be influenced rather by the actual meaning of the describer's combined words than by his unfortunate lack of technical procedure in description.

These check lists of tree names by Sudworth were official for the United States Forest Service, so the names in it were used by the foresters, but *Sequoia washingtoniana* (Winslow emend. Sudw.) Sudw. was little used by botanists. It was, however, adopted by J. G. Lemmon (1898: 171–172), former botanist of the California State Board of Forestry, and is currently used by Harlow and Harrar (1941: 193).

To return to the two names published by Winslow, *Taxodium Washingtonium* and *Washingtonia Californica*, we note that he did not assert that the name *Wellingtonia gigantea* Lindl. was invalid. As an American he disliked having the American big tree named for a British general, consequently he deliberately renamed it. It was unknown to the layman Winslow that Lindley's generic name *Wellingtonia* happened to be illegitimate, being a later homonym of *Wellingtonia* Meisner published in 1840 for a member of the Sabiaceae. So, actually, the new generic name by Lindley was invalid, and as a distinct genus the tree still needed a name, but what of the specific epithet *gigantea* given by Lindley? The earlier *Sequoia gigantea* Endl. (1847) was based on a sterile specimen collected by David Douglas; on a published letter of Douglas' referring apparently to the redwood; and on two references to Hooker and Arnott's names in *The Botany of Captain Beechey's Voyage*, in part referring back to the same Douglas reference, in part to *Abies religiosa*, and in part to *Abies bracteata*. When Lindley first published his *W. gigantea*, he introduced the subject by discussing the basis of *Sequoia gigantea* Endl. and eliminating it (1853*a*: 819). Lindley then briefly described a specimen of the big tree sent by Lobb from the Sierra Nivada [Nevada] of California. He named it *Wellingtonia gigantea*. It is perfectly clear from the previous context that the specific epithet used here, *gigantea*, was new, not one transferred from the confused and illegitimate *Sequoia gigantea* Endl. In consequence, the specific epithet *gigantea*, published in 1855 by Lindley, was legitimate, the first such one for the tree in question. So, when Winslow cited Lindley's binomial, the real basis of his concept, he had no right to reject Lindley's specific epithet *gigantea*. It has priority over the specific epithets of both the binomials proposed by

Winslow. Essentially, Winslow proposed two names for the big tree, representing two possible taxonomic placements — *Taxodium Washingtonium* or *Washingtonia Californica*. He gave more discussion of the name *Washingtonia*, but upon careful analysis it is seen that Winslow expressed no opinion, made no choice. He said (or meant to say), if it is considered a species of *Taxodium*, call it *T. Washingtonium;* if it is a genus, let it be called *Washingtonia Californica*. Under the International Code of Botanical Nomenclature (1952), a portion of Article 43 applies here: "A name . . . (2) which is merely proposed in anticipation of future acceptance of the group concerned, or of a particular circumscription, position or rank of the group (so-called provisional name), . . . is not validly published." The two names published by Winslow might fall under the class of alternative names, and these are proscribed, but only if published after Jan. 1, 1953. By implication, if published before 1953, alternative names are valid. However, they equally well fall under the first section of Article 43: "A name (1) which is not accepted by the author who published it, . . . is not validly published." By this provision both of Winslow's names are invalid. The fact that he proposed two of them without himself accepting either, does not necessarily protect them as alternative names, because he, the publishing author, did not accept them himself and they are in every sense provisional names. Also applicable is Article 73, "A name is illegitimate in the following cases: (1) If it was nomenclaturally superfluous when published, i.e. if the taxon to which it was applied, as circumscribed by its author, included the type of a name or epithet which ought to have been adopted under one or more of the rules." The epithet *gigantea* of Lindley was available for use under either *Taxodium* or *Washingtonia*. The fact that Winslow did not adopt it in either genus, renders his two epithets superfluous and illegitimate.

Taxodium giganteum (Lindl.) Kellogg & Behr (1855 [see ed. 2, 1873]: 51) was a name that appeared in print in a San Francisco newspaper, *The Pacific*, in a report of a meeting of the California Academy of Sciences on May 7, 1855. The two authors reported on this "Great Tree" of California. They published a new binomial for it and a four-line Latin diagnosis, then a long and detailed description in English. This description is more nearly complete than the previously published ones. It may have been wholly independent, even though numerous descriptive words and phrases are suspiciously like the ones used by Lindley in his earlier description of *Wellingtonia gigantea*. However, the description is longer and contains new details and larger measurement of height and diameter of tree. Hence, it seems certain that many of the details were from new reports or personal examination of specimens of the tree. Their binomial has usually been regarded as a new and independent name. It must be noted, however, that in their introductory paragraph it is stated that they "reported on the species of *Taxodium*, improperly described by English authors as *Wellingtonia*. . . ." They thus referred to the earlier publication of the tree by the Englishman, Professor John Lindley, as *Wellingtonia gigantea*. To the writers, it seems that the new name printed by Kellogg and Behr is better considered a transfer based upon *Wellingtonia gigantea* Lindl. Neither of the two alternative interpretations of the authorship has any great importance now. Botanists of today do not consider that this big tree belongs in the genus *Taxodium*, so this particular generic placement is not accepted. As a specific epithet, *giganteum*, if new with Kellogg and Behr, is later than its original publication as *Wellingtonia gigantea* Lindl. (1853) and of *Sequoia gigantea* (Lindl.) Dcne. (1854), so one of these two epithets, as the earlier, was available for transfer to some other genus, but not to *Sequoia*, because of the still earlier *Sequoia gigantea* Endl. (1847), which is a synonym of *S. sempervirens*.

Sequoia Wellingtonia Seemann (1855: 27)

was published in a column of current notes, without a real title to the article, but signed by Seemann, the editor of the journal. He referred to the article in which Winslow rejected as distasteful the name *Wellingtonia gigantea* Lindl. for the big tree and proposed for it the provisional names *Taxodium Washingtonium* and *Washingtonia Californica*. Seemann rejected both of Winslow's names as invalid. Then in a footnote he mentions examining at Kew the specimens on which *Wellingtonia* was founded. He observed that they were identical with *Sequoia sempervirens*, saying, "Der Unterschied steht einzig und allein auf dem Papiere, nicht in der Natur." Though boldly stated in this manner, his meaning was, apparently, that he found no generic distinctions between *Wellingtonia* and *Sequoia*. He pointed out that the specific epithet *gigantea* could not be transferred to *Sequoia*, as it would there be a later homonym of *S. gigantea* Endl. He then proposed a new name for the big tree—*Sequoia Wellingtonia* Seem.—and mentioned receiving satisfactory dried specimens of it from Herr F. Scheer. From the context, and from the fact that he was renaming Lindley's *Wellingtonia gigantea*, it is evident that Seemann's new specific epithet was the generic name of Lindley. Hence, Seemann wrote it, and it may still be written, *Sequoia Wellingtonia*, the specific epithet being capitalized. This binomial supplied the first legitimate specific epithet for the big tree in the genus *Sequoia*. Three years later Seemann published (1858) an extended account of his *Sequoia Wellingtonia*. It already had an extensive literature, and his brief references added up to half a column. For instance, in the year 1856, there were in the *Gardeners' Chronicle* references to the big tree in 14 different articles. Seemann summarized these accounts, both the nontechnical accounts of the tree and the impressions of it by travelers. He referred to the publication by Lindley of the big tree as a separate genus *Wellingtonia gigantea* and recounted how this was resented by many Americans as a national affront. An American on the Atlantic coast renamed it *Americus gigantea*, while one on the Pacific coast renamed it *Taxodium Washingtonium* or *Washingtonia Californica*. Seemann had in 1855 formed the opinion that the big tree was not generically distinct from the redwood and had curtly rejected Lindley's genus *Wellingtonia*. Again, in this second account he kept to this view. He tabulated the synonomy of the two species, *Sequoia sempervirens* and *Sequoia Wellingtonia*, and for the latter recorded the vernacular names, "Mammoth-tree, Big-tree, Wellingtonie."

For *Sequoia Wellingtonia*, Seemann published a large, full-length engraving. He detailed the location of the several known groves. He gave the various estimated and recorded sizes of the trees and estimates of their ages. Then, finally (p. 353), he gave a methodical description of the big tree, its trunk, bark, wood, leaf forms, and briefly of the flowers and cones. This lengthy account in 1858 completed, but maintained unchanged, his concept of *Sequoia Wellingtonia* Seem. first published in 1855.

For those botanists who refuse to recognize the big tree as a genus and insist on retaining it in the same genus as the redwood, the first legitimate name is *Sequoia Wellingtonia* Seem. (1855). This was adopted by Lemmon (1898: 171–172). A repressed choice for this classification was indicated by Little (1944: 277) in his new check list of the trees of the United States. He said, "*S. wellingtonia* is the proper name since 1930 under the International Rules of Botanical Nomenclature. A majority of the botanists in California consulted prefer to continue the illegitimate name *Sequoia gigantea*, which is so well established in many publications about these remarkable trees. In the interests of uniformity and of elimination of confusion in names, the name *S. gigantea* is here accepted by the Forest Service committee, though my [Little's] personal choice would be *S. wellingtonia*." It seems that Little was overruled by the other five members of the committee which consisted of his senior

dendrologist, Dayton (who had previously polled the Californian botanists and reported their preference for *S. gigantea*), of a representative of wildlife management, a wood technologist, one of timber management, and one of range management. Little rejected the tree as a genus, classified it in *Sequoia*, understood the rules of nomenclature and correctly applied them, and his chosen name was then rejected by the committee representing the various branches of forestry.

Gigantabies Wellingtoniana J. Nelson (published under the pseudonym Senilis) (1866: 79–83) included a new specific epithet for the big tree. We have already discussed the status of *Gigantabies* while considering the generic names of the big tree. Nelson explained at length and in effusive style that his deliberate renaming of *Wellingtonia gigantea* Lindl. was because of his dislike of generic names honoring people. He included a lengthy description, citation of its occurrence in Calaveras County, Upper California, mention of visitors who had reported about the grove—Murray, Black, Grosvenor, Renny, and others—but did not cite any actual specimens. It is perfectly clear that his names applied to the big tree previously described and given legitimate specific epithets by Lindley and by Seemann, and that he knew of one, if not of both, of these epithets. His epithet was superfluous and illegitimate. From the 1952 International Code, the following apply: Article 73, "A name is illegitimate in the following cases: (1) If it was nomenclaturally superfluous when published. . . ." Also, Article 79, "Specific and infraspecific epithets are illegitimate in the following special cases and must be rejected . . . (4) When they were published in works in which the Linnean system of binary nomenclature for species was not consistently employed." Both of these rules apply and definitely outlaw the epithet *Wellingtoniana* of Nelson.

CONCLUSION: For those botanists who, like the writers, see generic significance in the impressive total of fundamental morphological differences briefly stated herewith, the big tree was correctly classified by Buchholz (1939: 536) as *Sequoiadendron giganteum* (Lindl.) Buchholz, but because of the existence of the earlier name *Americus* Anon., we propose that the generic name *Sequoiadendron* be made a nomen genericum conservandum.

SUMMARY

The proposal in 1939 by Buchholz that the Californian big tree, formerly placed in *Sequoia*, be classified as a monotypic genus, *Sequoiadendron*, is reviewed. The morphological differences between the two are numerous and generically significant, so the latter is accepted as a distinct genus. The botanical and nomenclatural history of the two is reviewed. The redwood remains unchanged as *Sequoia sempervirens* (D. Don in Lamb.) Endl. For those who insist that the big tree must remain in that same genus, the legitimate name is *Sequoia Wellingtonia* Seem. For those who agree with the writers that the big tree is amply distinct and represents a genus, there are still problems in nomenclature. The generic name *Wellingtonia* Lindl. is a later homonym and illegitimate. *Washingtonia* Winslow is a later homonym and invalid. *Gigantabies* J. Nelson is not a generic name. *Americus* Anon. is legitimate, but not worthy of adoption. *Steinhauera* Presl, based upon fossil plants, is illegitimate for application to a genus of living plants. *Sequoiadendron* Buchholz is a good name, based upon careful and original research on the plants. Though later than *Americus*, we propose that *Sequoiadendron* be adopted as a nomen genericum conservandum. Among the published specific epithets, the following are illegitimate and unavailable for use with *Sequoiadendron: Sequoia gigantea* Endl., *S. Wellingtonia* Seem., *S. gigantea* Dcne., *Taxodium Washingtonium* Winslow, *Washingtonia Californica* Winslow, *Gigantabies Wellingtoniana* J. Nelson, *S. washingtoniana* (Winslow emend. Sudw.) Sudw., and *Steinhauera gigantea* (Lindl.) Ktze. in Voss. The first available epithet was published in the binomial *Welling-*

tonia gigantea Lindl., and this epithet, distinct from the earlier *Sequoia gigantea* Endl., is definitely based upon the big tree and is available for use in the combination *Sequoiadendron giganteum* (Lindl.) Buchholz, if that generic name is subsequently conserved, as here recommended.

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Some Results from the Swedish "Albatross" Cruise[1]

HANS PETTERSSON[2]

SIX YEARS AGO, late in November, 1947, the Swedish research ship, the 1,450-ton motor schooner "Albatross," on its round-the-world cruise entered the harbor of Honolulu, where we had a magnificent reception. Two years later, in December, 1949, I was invited over here from the Mainland to give a preliminary survey of the main results of the cruise obtained through work in the Oceanographic Institute in Göteborg and in collaborating institutes in Sweden and abroad to that time.

Now, 4 years later, I am happy to say that fair progress has been made in this work, so that already some volumes of our "Reports from the Swedish Deep-Sea Expedition" have been printed, and more are coming.

We have also had the satisfaction of seeing other deep-sea cruises, sent out from Denmark, from Great Britain, and from the United States, working on the lines the "Albatross" followed, partly with aid of the technique developed in Sweden, and also that their results have on several important points confirmed our own.

I shall now give a summary of the results gained since I was here last, particularly those in submarine geology.

A glance at a map of the world which indicates the depths of the oceans will show you immediately why the Pacific Ocean, and especially its central parts, are the cherished hunting ground of deep-sea oceanographers. Here is the greatest area of ocean deeper than 4,000 metres, or 13,000 feet. From these depths the Hawaiian Islands rise as great mountains.

Our cruise here through the equatorial Pacific Ocean, from the Galápagos Islands to the Philippine Islands, crisscrossing the equatorial current system, took us 5 months to accomplish, one third of the time alloted for our whole cruise. The course we followed is shown on the map accompanying my earlier article in Pacific Science (2[4]: 231–238). Between Tahiti and Oahu we followed the course of H.M.S. "Challenger," made over 70 years earlier, but in the opposite direction. Here Sir John Murray had found indications of the sediment having accumulated with extreme slowness. Here, therefore, the piston corer, invented and manipulated on board by Dr. Kullenberg, would be likely, with its maximum range of 60 to 70 feet, to penetrate further backward in time than anywhere else.

Thanks to radioactive age-determinations made in Göteborg on different sediment layers in our cores, we are now able to say that the Mid-Pacific Red clay increases in thickness by about 1 millimetre in 1,000 years. This implies that, for adding 1 inch to the sediment carpet in that area, some 25,000

[1] Digest of a lecture delivered at the University of Hawaii, January 6, 1954, sponsored by the Hawaiian Academy of Science, the Geophysical Society of Hawaii, and the Hawaii chapter of the Society of the Sigma Xi. Manuscript received February 5, 1954.

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years of uninterrupted sedimentation are required.

Only a few words about these radioactive age-determinations, as applied to submarine chronology. Some 15 years ago I ventured to explain the mysteriously high radium content of the Red clay and of the Radiolarian ooze as due to a precipitation onto the ocean bottom of radium's mother element, ionium, together with ferric hydroxide. Granting this to be true, the content of "ionium-supported" radium in the deposit should decrease with increasing distance below the sediment surface at a rate correlated with the half-period of ionium decay, that is, to 50 per cent in 83,000 years, to 25 per cent in 166,000 years, etc. This presupposes that there is no sensible amount of the ancestral element, uranium, present in the deposit. Both assumptions, a lack of uranium and a surplus of ionium near the sediment surface, have been confirmed recently through investigations on "Albatross" cores by Professor F. Hecht in Vienna and by Dr. E. Picciotto in Brussels, whereas Dr. V. Kröll in Göteborg has carried out most of the radium determinations.

However, age-determinations from radium measurements alone are not such a simple, straightforward work as the ionium-precipitation hypothesis would lead us to believe, possibly because of radium's tendency to migrate downward in the sediment column, leaving behind its more stationary mother-element, ionium.[3] Although this makes the technique more complicated, it is still possible, with due precautions, to use measurements of the vertical distribution of radioactivity along a sediment core as a means of determining its past rate of deposition.

There are, however, also other, more indirect methods for attacking the difficult problem of submarine geochronology, for example, the dating of different sediment layers. One of these methods depends on a careful analysis of the calcareous Foraminifera shells present in different strata and the presence of more or less heat-loving or "thermophile" species. This really amounts to a paleoclimatological study of the temperature variations in the surface layers of the ocean which have become reflected in the plankton organisms it has contained. In this manner, indications by the "thermometer" which a sediment core represents can be linked up with known and datable variations in the temperature on the continents due to cold (glacial) and warm (interglacial) ages. This, so to say, biological age-determination was first extensively used on cores from the German "Meteor" expedition by W. Schott and later on "Albatross" cores by Schott in Göteborg, by C. D. Ovey in London, and especially by F. Phleger, F. Parker, and J. Pierson in the Scripps Institution of Oceanography in La Jolla.

The geologist of our expedition, Dr. G. Arrhenius, a year ago published a comprehensive study of the "Albatross" cores from the eastern Pacific Ocean. In this pioneer work of great importance to deep-sea research, Arrhenius has very carefully compared different sediment components such as carbonate of lime, humus-carbon, nitrogen, phosphorus, iron, manganese, titanium, etc. In this manner and utilizing also the biogenic components, Arrhenius was able to correlate the different strata in cores from very wide regions and to ascribe these strata to different stages and substages of continental glaciation. Assuming titanium to be the least variable of all the inorganic components in the deposits, Arrhenius calculated the rate of accruement of titanium to the sediment from the "lutite veil," that is, the finest clay-particles suspended in ocean water. In this manner he calculated the "titanium age" of the different layers in different cores. He further obtained a basis for this chronology from measurements by the radio-carbon dating method made in collaboration with F. Libby and Kjellberg of

[3] Recent ionium determinations in our Red clay samples do not lend support to this migration hypothesis, except possibly as a contributory influence on the radium distribution in the cores.

the rate of deposition in a certain core from the region considered. Arrhenius also drew inferences from his core analyses regarding the intensity and location of the equatorial current system during the Quaternary Age. Not all Arrhenius' conclusions are accepted by other workers in the field, especially not the titanium-age calculations. Recent discoveries of an unexpectedly high titanium content in certain metamorphosed rocks on the Hawaiian Islands appear to make it more difficult to accept any conclusion regarding a constant rate of accruement of this element to the bottom sediments. Nevertheless, the thesis published by Arrhenius is of outstanding value to future work on deep-sea geology.

There are some aspects of our results which I consider to be of particular interest. One of these regards submarine volcanism. It is well known that the Pacific Ocean, both in its peripheral and in its central parts, has been an area of extensive volcanic activity and that its numerous islands have largely been built up from submarine volcanoes, the most monumental of which are these islands of Hawaii. The "Albatross" cruise afforded ample evidence that submarine volcanic action has also worked in a horizontal direction, producing extensive lava beds on the ocean floor.

For many years I have been of the opinion that submarine volcanic activity must also have had important geochemical effects by releasing magmatic volatiles like carbon dioxide and mineral acids and that these have been active in dissolving away the lime from calcareous oozes and transforming them into Red clay and Radiolarian ooze. This would explain how these sediments can have been formed during the Tertiary Age when the temperature of the bottom water in great ocean depths must have been much higher than at present and when no Antarctic Bottom Current, generally held responsible for the dissolving away of the lime, swept over the ocean floor. That Red clay of Tertiary Age, formed under these conditions, actually exists in great depths was first proved by the long cores raised by the "Albatross." Some prominent geologists and oceanographers, such as W. Rubey and R. Revelle, have argued that the water filling the ocean basins has also been largely derived from magmatic volatiles released from the substratum beneath the ocean floor.

It seems to me that the central Pacific Ocean, especially the vicinity of the Hawaiian Islands, affords an ideal field for testing this hypothesis, a view I found strongly supported by the late master of volcanology, Professor T. Jaggar.

A most important fact learned from the "Albatross" cruise, afterward confirmed from other expeditions, is the unexpectedly high geothermal gradient in the deep-sea deposits, quite as high as, if not even higher than, the average value for the continents. It seems reasonable to assume that the supply of geothermal energy below the ocean floor may be a sign of an extensive "latent" volcanism, whatever the ultimate source of this accumulated geothermal heat may be.

Two more of our results appear to me worthy of being mentioned here. Thanks to co-operation with our great authority on explosives, Professor W. Weibull of the Bofors Armament Works, we were able during the cruise to measure, for the first time, through a seismic method the thickness of the sediment carpet spread over the ocean floor. Geochemical speculations by eminent authorities had given 7,000 feet as a probable average value for the thickness of the Red clay, with higher values for other, more rapidly accumulating sediments. Weibull's reflexion measurements gave comparable, in one case even higher, values for the central Atlantic Ocean between Madeira and the Mid-Atlantic Ridge. But to our great surprise the values found in the central Pacific and also in the Indian Ocean were only a small fraction of the theoretical figures. This latter fact has been amply confirmed through later measurements by refraction shooting methods used both from the British research ship "Challenger" and

from the "Capricorn" and other expeditions sent out from Scripps Institution. So far no explanation for this surprisingly small thickness of sediment in the Pacific Ocean, generally assumed to be the oldest sea basin, has been proposed. Possibly a conversion of already deposited sediment layers into magmatized crusts through submarine volcanic activity may be considered, or else an extenuation of the seismic waves through intermediate lava layers may be assumed.

Finally I have to mention a great puzzle to deep-sea geologists which consists in the displacement of already deposited sediments through submarine erosion or other agencies. Investigations on the Radiolarians in "Albatross" cores, especially such from the central Pacific Ocean, carried out in Göteborg by a young Australian scientist, W. Riedel, have proved that in some localities Radiolarians of recent origin are mixed with such of Tertiary age. Similar observations on Foraminifera have been made in the Atlantic Ocean by Phleger, working on "Albatross" cores, by Ericson working on Atlantic cores raised from the "Atlantis," and on Pacific "Albatross" cores by Brotzen. On the other hand, by means of optical methods developed by Jerlov during the "Albatross" cruise, it has proved possible to find evidence of submarine erosion due to bottom currents sweeping over ridges or banks. To assign all such cases or sediment transportation to the so-called tufbidity currents studied by Kuenen and others does not appear a sufficient explanation.

Our fond hopes that the deposits from great ocean depths constitute records which have remained undisturbed for millions upon millions of years are obviously not always in accordance with established facts. However, to infer from this fact that deep-sea coring only gives falsified abstracts from the "records of the deep" is a false conclusion. Already Arrhenius' pioneer work on cores from the eastern Pacific Ocean has proved what valuable results the study of long sediment cores can give for increasing our highly limited knowledge of the sediment carpet in great ocean depths. I believe this will become still more evident when, within a few years, the "Reports from the Swedish Deep-Sea Expedition" will have appeared complete in print.

When the "Albatross" was here in December, 1947, I emphasized in a lecture held before the Honolulu Chamber of Commerce that your city has an unrivaled position for the study of the deep ocean floor and for unraveling its secrets. I am happy to find now that this view has been gaining support from leading men of your University. I have had great pleasure in finding also what important work is being carried out from the new Marine Laboratory on Coconut Island and by the U. S. Fish and Wildlife Service on your campus, with results which admirably supplement our hydrographic sections across the Equatorial Current System. I sincerely hope that when I come here again, as I hope to do, there will be a new centre for deep-sea research in operation here, and with this wish I beg to thank you for having listened to my exposition tonight.

Decapodous Cephalopod Mollusks from the Marshall Islands[1]

GILBERT L. VOSS[2]

THE CEPHALOPODS recorded in this report were collected in the Marshall Islands partly during Operation Crossroads by the oceanographic section of Joint Task Force One under the direction of Commander Roger Revelle in 1946 and the Bikini Scientific Resurvey under the direction of Captain Christian L. Engleman in 1947, and partly by the Pacific Science Board. Although the collection is a small one numbering only seven species and 27 specimens, it comprises the only records from this group of islands since the report by Hoyle in 1904 on the collections made by the "Albatross" in 1899–1900.

Of the 27 specimens represented, only a single specimen was collected in 1947, five were taken by R. W. Hiatt under the auspices of the Pacific Science Board at Arno Atoll, and those remaining were collected in the original survey made in 1946. The Operation Crossroads material was collected by the following individuals: J. C. Marr, L. P. Schultz, Birch, Frank Cali, J. P. Morrison, Myers, and Smith. It is interesting to note that Hoyle listed only one species of squid taken by the "Albatross" in these waters, *Euprymna stenodactyla* (Grant), of which ten specimens were collected in 1946.

The present specimens were all collected at the surface at night by means of a dip net and submarine light.

[1] Contribution No. 122 from the Marine Laboratory, University of Miami. Manuscript received September 24, 1953.

[2] The Marine Laboratory, University of Miami, Coral Gables, Florida.

The author wishes to thank Dr. Grace E. Pickford, of the Bingham Oceanographic Laboratory, and the Pacific Science Board for the opportunity to work up the present material. He is also grateful to the officials of the U. S. National Museum, and especially Dr. Harald A. Rehder, Curator of Mollusks, for making the facilities of that institution available during the course of the study.

Division MYOPSIDA

Family *SEPIIDAE*

Genus SEPIA Linnaeus, 1758

Sepia bandensis Adam, 1939

Sepia bandensis Adam, 1939*a* (original description).

LOCALITIES: Arno Atoll; Ine village, Ine Island, from lagoon reef flat near outer portion; R. W. Hiatt, June–September, 1950. Three females, U. S. N. M. 574869.

Arno Atoll; Ine Island, from outer lagoon reef slope; R. W. Hiatt, June–September, 1950. Two females, U.S.N.M. 574868.

NOTES: The five specimens from Arno Atoll have been placed, with some hesitation, in the above species. The minute posterior spine on the shell and the arrangement, size, and distribution of the suckers of the tentacular club appear to be identical with those described and figured by Adam (1939*a*). Otherwise their possible relationship to *S. tuberculata* and *S. papillata* seem to offer the same problem as discussed by him.

The specimens show a considerable rugosity on the dorsal surface of the head, the dorsolateral, and parts of the ventral surface of the mantle. This may have been caused by shipment wrapped in cheesecloth but this is uncertain. There are several tubercles over the eyes, a small patch of six or seven below each eye at the base of the arms, and a double row of elongated papillae or ridges on the latero-ventral surface of the mantle near the fins.

It is interesting to note that no *Sepia* have been recorded from the Hawaiian Islands, which appear to share an otherwise similar cephalopodan fauna, although they are numerous to the westward throughout the East Indies, the Philippines, and Japan. The present specimens appear to be the most eastern Pacific record to date.

Family *SEPIOLIDAE*

Genus EUPRYMNA Steenstrup, 1887

Euprymna stenodactyla Grant, 1835

Sepiola stenodactyla Grant, 1835 (original description).
Euprymna stenodactyla, Hoyle, 1904.

LOCALITIES: Bikini Atoll, lagoon; Schultz and Morrison, April 23, 1946. One male, U.S.N.M. 574219.

Bikini Atoll, lagoon; Schultz, April 24, 1946. One male, two females, U.S.N.M. 574257.

Bikini Atoll, lagoon; Schultz, April 26, 1946. One female, U.S.N.M. 574253.

Rongelap Atoll, lagoon; J. Marr, June 27, 1946. Two males, two juveniles, U.S.N.M. 574826.

Bikini Atoll, lagoon; Myers, Schultz, and Smith, July 15, 1947. One male, U.S.N.M. 574827.

NOTES: The present specimens have been placed in this species, but their eventual disposition must await a much needed thorough revision of the genus. Hoyle's (1904) description of this species, based upon the "Albatross" material from Arno Island, is very detailed and supplements Grant's (1835) rather limited description in many ways. As Berry (1912: 315) notes, the differences between *E. stenodactyla*, *E. scolopes*, and *E. morsei* are trivial and based almost entirely upon the hectocotylized arm of the males. Indeed, as he remarks, the description of one *Euprymna* might very well do for all the others except for this organ.

A comparison of the present specimens with the type of *E. scolopes* Berry from the Hawaiian Islands showed a number of differences in the hectocotylized arm, the present specimens having larger suckers in only two rows, but the character of the hectocotylized arm being more dorsally curled in *E. scolopes* does not seem tenable, as this is in direct relationship to the preservation of the animal. The name *scolopes* is misleading, as the present specimens also have distinctly palisaded pedicels on the hectocotylized arms.

As remarked above, the modified suckers of the right dorsal arm in the male are very large, in only two regular rows, and are born upon the ends of heavy stalks or pedicels. The rings are smooth and are closed by fleshy protuberances or dactyls which give them the appearance described by Hoyle and Berry of having only a dorsal slit or mouth-like opening.

Family *LOLIGINIDAE*

Genus SEPIOTEUTHIS Blainville, 1824

Sepiotheuthis lessoniana (Lesson, 1830)

Sepioteuthis lessoniana Ferussac, 1826 (nomen nudum).
Sepioteuthis lessoniana Lesson, 1830 (original description).

LOCALITIES: Rongelap Atoll, lagoon; J. C. Marr, June 27, 1946. Three females, U.S.N.M. 587133.

Rongerik Atoll, lagoon; J. C. Marr, May 31, 1946. One male, three females, U.S.N.M. 587134.

Rongelap Atoll; Lomuilal Island; Schultz,

July 31, 1946. One male, U.S.N.M. 574197.

NOTES: This species has been so well covered by Adam (1939*b*) that no added remarks seem necessary. Both Adam (*loc. cit.*) and Sasaki (1929) have considered the Hawaiian *S. arctipinnis* Gould as synonymous with *S. lessoniana*, and the occurrence of the species at the Marshall Islands offers a still closer connection between the Japanese and Hawaiian ranges. A single large specimen from Tumon Bay, Guam Island, Mariannas, collected by Gressitt and Ingram on January 8, 1946, might be added here to supplement their distribution. Only one of the Marshall Islands specimens contains the large round spots about the edges of the fins as illustrated by Sasaki.

Division OEGOPSIDA

Family *ENOPLOTEUTHIDAE*

Genus ABRALIA Gray, 1849

Abralia astrosticta Berry, 1909

Abralia astrosticta Berry, 1909 (original description).

LOCALITY: Rongelap Atoll; South Pass; Birch and Marr, May 16, 1946. One female, U.S.N.M. 587132.

NOTES: A single specimen of this rare and little-known squid was obtained from South Pass, Rongelap Atoll, and is identical with the detailed description by Berry (1912) of this species from the Hawaiian Islands. Unfortunately Berry's type, U.S.N.M. 214313, was totally destroyed through improper preservation, and only the bottle with the original label is extant.

As the description of this species by Berry (1912) is adequate, I am withholding further comment for a revision of the genus which is now underway. It should be noted, however, that this specimen with a mantle length of 57.0 millimeters is apparently full grown and the assumption by Pfeffer (1912) that this species represents a growth stage (*Comp-soteuthis*-stage) is quite without substantiation. There is no terminal swelling on the end of the ventral arms, and the arrangement of the photophores seems consistent with Berry's description. This apparently is the only specimen of this rare squid now extant in collections.

Family *OMMASTREPHIDAE*

Genus HYALOTEUTHIS Gray, 1849

Hyaloteuthis pelagica (Bosc, 1802)

Sepia pelagica Bosc, 1802 (original description).

Ommastrephes pelagicus, Ferussac and d'Orbigny, 1839.

Hyaloteuthis pelagicus, Pfeffer, 1900.

LOCALITY: Eniwetok Atoll; 4/5 mile south of Rigili Island; Schultz and Cali, May 25, 1946. One gravid female, U.S.N.M. 574251.

NOTES: This specimen with a mantle length of 53.0 millimeters agrees very well with Pfeffer's (*op. cit.*) and Sasaki's (1929) figures and descriptions, and is nearly identical with the latter's specimen of 50.0 millimeters mantle length from the Bonin Islands. It has been reported in the Pacific from the following localities: South Pacific (Pfeffer), Satsuma and the Bonins (Sasaki), and north of Hawaii (Rehder). This new record from the Marshall Islands therefore considerably increases its known range in this ocean. It is easily recognized by the presence of 19 large round to oval photophores regularly distributed over the ventral surface of the mantle.

Genus SYMPLECTOTEUTHIS Pfeffer, 1900

Symplectoteuthis oualaniensis (Lesson, 1830)

Loligo oualaniensis Lesson, 1830 (original description).

Ommastrephes oualaniensis, d'Orbigny, 1845.

Symplectoteuthis oualaniensis, Pfeffer, 1900.

LOCALITY: Bikini Atoll; Bikini Channel; Schultz, April 6, 1946.

NOTES: This specimen agrees well with Sasaki's (1929) description. Apparently only the left locking cartilage was fused in this specimen, but the area of attachment is so small that the right side may have been overlooked and torn loose. The present individual is the first record of this species from this area of the Pacific, although Schauinsland (1899) reported it from Laysan Island in the Hawaiian group and Sasaki (*op cit.*) reported it from Formosa, Okinawa, and Japan. It is apparently well distributed in the Indo-Pacific area.

Among the specimens in this collection were three squid, which were very difficult to identify, taken from the stomachs of sea birds. They were partially digested and then excessively hardened in alcohol so that the arms and tentacles are fused together and exceedingly brittle. Upon dissection they proved to be ommastrephids, and they seem to be referable to the above species although the determination is questionable.

LOCALITIES: Bikini Atoll; Ourakaen Island; Morrison, May 2, 1946. One from booby and the other from white-capped noddy. U.S.N.M. 574263.

Rongelap Atoll; Burok Island; Morrison, July 24, 1946. No other data. U.S.N.M. 574267.

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NOTES

Distribution of the Algal Genera *Rhipilia* and *Sargassum* in the Central Pacific

In assembling marine algal floristic information on the Central Pacific, certain peculiarities have come to light. One of these is an apparent exclusiveness of range between the genera *Rhipilia* and *Sargassum.*

Glassman (Amer. Midland Nat. 48: 735–740, 1952) reports two species of *Sargassum* from Ponape. He found no *Rhipilia.* Neither genus has been found in available collections from Wake Island or Guam. Taylor (Plants of Bikini, pp. 70–73, 1950) reports *Rhipilia* from the four northern Marshall atolls he studied — Eniwetok, Rongelap, Bikini, and Rongerik. Despite a thorough study he did not find *Sargassum. Rhipilia geppii* Taylor but not *Sargassum* is present in collections from Arno Atoll (southern Marshalls) and Butaritari (northern Gilberts).

Of the two genera, *Sargassum* is abundant in the Hawaiian archipelago. *Rhipilia* seems to be absent. Neither genus has been found during recent collecting at Johnston Island. In collections seen from Palmyra (Line Islands), *Rhipilia geppii* has appeared but not *Sargassum.* Howe and Lyon (Hawaii Col. Pubs., Bul. 4: 31–32, 1916) reported neither genus in their brief discussion of the algae of Palmyra. Sargassum is absent, likewise, in collections at hand from Canton Island in the Phoenix Group. Setchell (Carnegie Inst. Wash., Pub. 341, parts 1, 3, 1924) found two species of *Sargassum* at Tutuila in American Samoa, no *Rhipilia;* and at Rose Atoll, neither genus.

No *Sargassum* was found in collecting at Aitutaki in the Cook Islands; however, relatively no more than a glimpse of the reef and lagoon was had. No *Sargassum,* nor even *Turbinaria,* was seen on four northern Tuamotuan atolls visited, although intensive search was made at Takume and Raroia, where *Rhipilia geppii* was found in abundance. At Tahiti, Setchell (Calif. Univ., Pubs. Bot. 12: 61–142, 1926) distinguished four species of *Sargassum* (and the genus is indeed conspicuous there) but not *Rhipilia.*

Setchell reports an alga, *Avrainvillea lacerata* (Harv.) J. Ag., as occurring at Tahiti "in extended patches in deep shaded holes in basalt rocks, upper littoral zone" and elsewhere there. This does not sound like the ecology of *Rhipilia geppii.* To be sure, Taylor after studying this material notes that this species though suggestive is distinct from his *Rhipilia geppii.* He notes, too, that this *Avrainvillea* occurs at Washington Island (Line Islands), in the northern Marshalls, and in Java. This genus is considered to be a close relative of *Rhipilia.*

The islands which apparently lack *Sargassum* are not without algae of world-wide pantropic or Indo-Pacific distribution. As an example, Palmyra has yielded *Asterocytis ornata* (C. Ag.) Hamel, a world-wide species (at least poleward through temperate waters); pantropic elements such as *Bryopsis pennata* Lam.; and Indo-Pacific elements such as *Goniolithon frutescens* and *Caulerpa serrulata.* Similar evidence for other islands where *Rhipilia* is present and *Sargassum* absent militates against describing the border between this apparent distribution of the two genera as a division between zones. A more likely hypothesis is that there is a gradual biotic change as this area is passed through and that the large dis-

tances separating the islands together with restriction of the consideration to just two, or few, genera leaves the impression of zonation.

One of the first explanations for these indications of exclusiveness in range to come to mind is that *Sargassum* only occurs around high islands (igneous substrata, drainage, etc.). However, both Lemmerman (Bot. Jahrb. 34: 607–663, 1905) and Reinbold-Itzehoe (Naturw. Ver. zu. Bremen, Abhandl. 16: 287–302, 1899) record *Sargassum* from Laysan (Hawaiian group), which probably must be classed as a low island (carbonate substrata, etc.). It is similarly found about low islands in the Atlantic. An interesting test of this hypothesis would be analysis of the presence or absence of these genera in the Marquesas Islands, which are a group of high islands as near the equator as are the low Phoenix and Line islands.

Even though *Sargassum,* and not *Rhipilia,* might occur in the Marquesas, one is still left with the interesting observation that there is an area in the Central Pacific (i.e., between about 141°W and 165°E, and between about 16°N and 16°S) in which *Sargassum* has not yet been reported (Samoa is at about 14°S) and outside of which, latitudinally, *Rhipilia geppii* has not been found. This same area is one of relatively inactive, or "dead," reefs.

This central region may prove to be an important biotic province. The relatively great development of such species of the genus *Porolithon* as *P. gardineri, P. aequinoctiale,* and especially *P. onkodes* in this area supports this hypothesis.

Sargassum is readily noted and frequently collected, if present, even by chance visitors who are not primarily phycologists. *Rhipilia,* however, grows in relative seclusion, is usually less than 5 centimeters tall, and is, therefore, not frequently collected by others than phycologists. *Rhipilia geppii* grows among dead coral branches (e.g., between *Pocilopora* branches just behind actively growing lagoon reef edges and usually a decimeter or two below the upper general level of the coral surface). As a rule it looks like clusters of poorly formed dark green, felt-like, noncalcareous blades on indistinct stems.

Specimens of *Sargassum* from any other places in the Central Pacific, as well as notices of collections of *Rhipilia,* could be valuable contributions toward providing the means of a better explanation for this apparent mutual range exclusion phenomenon. — *Maxwell S. Doty, Department of Botany, University of Hawaii.*

Substitute for an Invalid Generic Name in the Crustacea

Attention has been called to the preoccupation of the generic name *Mesocaris* Edmondson (Bernice P. Bishop Mus., Occas. Papers 10 (24): 13, 1935) by *Mesocaris* Ortmann (Ergebn. Plankton-Exped. 2 (Gb): 73, 82, 1893). To validate the genus of 1935, I propose to substitute the name *Antecaridina* for *Mesocaris* Edmondson. — *C. H. Edmondson, Bernice P. Bishop Museum, Honolulu.*

News Notes

A much needed *Directory of Hydrobiological Laboratories and Personnel in North America,* edited by R. W. Hiatt and a board of persons outstanding in the general field of hydrobiology, has been published by the University of Hawaii Press. It includes 187 fresh-water and marine laboratories. A wealth of information is given, including address, affiliation, objectives and scope of activities, equipment, description of accommodations available, instructional program, and staff. The personnel are listed separately, with a biographical sketch of each. Complete with a cross-reference index to the laboratories, this work will be extremely useful to all concerned with any aspect of hydrobiological science.

HIATT, R. W. *Directory of Hydrobiological Laboratories and Personnel in North America.* Auspices of the Advisory Committee on Hydrobiology to the Office of Naval Research. ix + 324 pp., 22 figs. University of Hawaii Press, Honolulu. $3.75.

A revision of S. F. Light's manual, *Intertidal Invertebrates of the Central California Coast,* by Ralph I. Smith and several coauthors will be useful to all persons interested in the coastal life of western North America, even though it is prepared primarily as a guide to the fauna of the central California coast. A short discussion of each major taxonomic unit is followed by keys which lead to species names where possible; a list of species follows. Illustrations are included to assist in use of the keys. Sections on marine algae and flowering plants, suggested field studies, and a rather extensive bibliography add much to the usefulness of this book.

SMITH, R. I., *et al. Intertidal Invertebrates of the Central California Coast.* xiv + 446 pp., 138 figs. University of California Press, Berkeley and Los Angeles. $5.00.

Sheet 1 of a geological map of New Caledonia (scale 1:100,000) has just been received. Nine more sheets are in process of reproduction. This constitutes the first such map of New Caledonia since that of Piroutet, 1917 (scale 1:1,000,000). The map is based on field work carried on since 1946 by a geological mission sent out by l'Office de la Recherche Scientifique Outre-Mer, l'Inspection générale des Mines et de la Géologie de la France d'Outre-Mer, and le Centre National de la Recherche Scientifique. The mission has consisted of P. Routhier, A. Arnould, and J. Avias.

Carte Géologique de la Nouvelle-Calédonie. La feuille 1: Arama-Poum; with explanatory notes. Published by l'Office de la Recherche Scientifique Outre-Mer, 20 rue Monsieur, Paris (7e). Also for sale by l'Institut Français d'Océanie, Boîte postale no. 4, Nouméa. 1,20 francs métro.